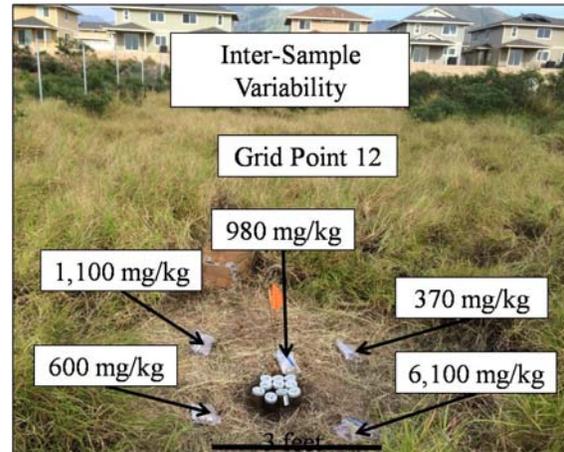
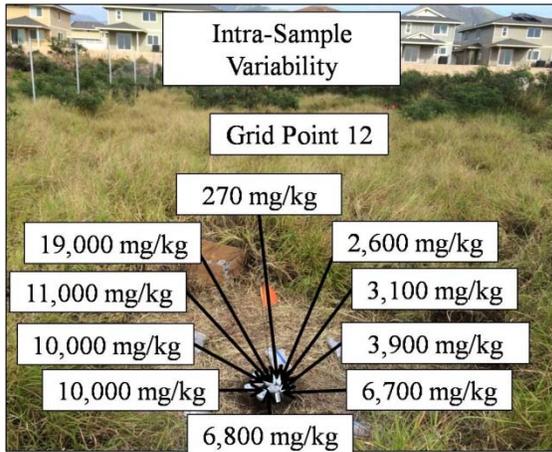


Small-Scale Variability of Discrete Soil Sample Data

Part 1: Field Investigation of Discrete Sample Variability



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Forward

This report presents the results of a field-based study of the variability of contaminant concentrations within unprocessed, discrete soil samples and between sets of co-located samples. The study is presented in two parts. Part 1 of the report summarizes the results of the field study and briefly discusses the implications of the findings on the use of discrete sample data for decision making in environmental investigations. A draft of Part 1 was published in October 2014. The most current update of this part of the study is dated March 2015. Part 2 of the study evaluates the causes of discrete sample variability and uncertainty and discusses implications for site characterization, risk assessment and remedial design based on discrete sample data in more detail.

This report will be updated and amended as needed in the future. Comments and suggestions are welcome and should be provided to Roger Brewer at roger.brewer@doh.hawaii.gov. Data tables presented in this report will be made available in Excel format along with the report on the HEER web page or are available upon request from the above contact.

“If I were given one hour to save the world, I would spend 59 minutes defining the problem and one minute solving it.”

Albert Einstein

May 2015 updates to October 2014 edition of Part 1:

General:

- Report title revised to *Small-Scale Variability of Discrete Soil Sample Data*;
- Tables and figures renumbered to reflect report section;
- Discussion and photos of suspected TPH- and PCB-infused, tarry nuggets of soil in samples from Study Site C added to Section 5.1 (Intra-Sample Variability);
- Scales added to map figures;
- Errors in grid point numbers corrected.

Other Key Updates:

- Section 4, Results. Relative Percent Difference, Standard Deviation and Relative Standard Deviation added to data summary tables.
- Section 5.3, Total Intra- and Inter-Sample Variability. Method used to estimate total discrete sample variability around individual grid points revised, based on adjustment of measured concentration for processed samples upwards and downwards with respect to mean RPD between minimum- and maximum-reported concentrations reported for intra-sample data set from same grid point. For illustration purposes only; accuracy of estimates is uncertain. Used to prepare box plots of total, estimated discrete sample variability around individual grid points (Part 2).

Acknowledgements

Funding for this project was provided through a grant from US Environmental Protection Agency-Region IX to the Hawai'i Department of Health, Hazard Evaluation and Emergency Response office. The US Coast Guard, Hawai'i Department of Natural Resources and the City and County of Honolulu provided access to study sites discussed in the report. Eric Wetzstein with the Honolulu office of AMEC and Matt Neal of Element Environmental provided field assistance for the collection of samples. Geotek Hawai'i provided use of a portable XRF for analysis of samples collected at the arsenic- and lead-contaminated sites (tests conducted by Marvin Heskett, then with Geotek Hawai'i). Fixed-laboratory analysis of the samples was carried out by Test America Laboratories.

The HEER office also gratefully acknowledges the numerous regulators and consultants in Hawai'i and on the mainland who provided technical input prior to and throughout the course of the project. Particular thanks are given to Bill Cutler for his detailed work on the geochemistry of arsenic-contaminated soils in Hawai'i similar to those included in this study. The results and conclusions of this project are specific to the authors of this report, however, and may not necessarily reflect the conclusions and opinions of those who provided outside assistance.

Executive Summary

This study evaluates the source and potential magnitude of decision error associated with the use of discrete sample data in environmental investigations. The project was carried out by staff of the Hawai'i Department of Health (HDOH), Hazard Evaluation and Emergency Response office (HEER) with assistance from Geotek Hawai'i and the Honolulu office of Test America Laboratories.

The results of this study are presented in two parts. This report presents Part 1 of the study and summarizes data collected as part of a field-based investigation of contaminant concentration variability within individual discrete soil samples and between closely located samples. A brief interpretation of the data and implications for the reliability of discrete soil sample data in environmental investigations is also provided. Part 2 of the study presents a more detailed review of the likely sources of contaminant concentration variability within and between discrete soil samples. A more detailed assessment of implications for potential decision error in site characterizations, risk assessment and remedial actions is also included.

The term “variability” is used in a very general sense for the purpose of this report to describe the range of contaminant concentrations in soil around a sample collection location at the scale of a typical, discrete soil sample. The field study was designed to help answer three basic questions: 1) “How variable is the concentration of a contaminant within an unprocessed, discrete sample with respect to the mass of soil typically used for laboratory digestion/analysis (e.g., 1 to 30 grams)?”, 2) “How variable is the concentration of a contaminant between co-located, discrete samples collected within a short distance of a given sample point?” and 3) “What are the implications for the reliable use of discrete soil samples in environmental investigations?” The first two of these questions are explored in Part 1 of this study. The latter question is explored in detail in Part 2 of this study.

The results of the study indicate that the concentration of a contaminant reported for any given discrete sample collected around a single grid point can vary dramatically, for example up to two orders of magnitude at Study Site C for PCBs. This is due to random, small-scale distributional heterogeneity of contaminants in soil at the scale of a traditional, discrete sample. A closer review of the data in Part 2 of the study indicates that the number of discrete samples required to reliably represent a targeted area and volume of soil likewise varies widely and is dependent on the magnitude of both large-scale and small-scale variability within the area.

The magnitude of this variability depends on multiple factors, including the physiochemical properties of the chemical (e.g., solubility, sorption coefficient, volatility, etc.), nature of the release (e.g., liquid vs solid), soil type and subsequent use of the area.

Variability in concentrations of arsenic at and immediately adjacent to grid points was relatively low at Study Site A where soils are believed to have been impacted by discharges of contaminated wastewater and/or runoff from nearby agricultural fields. The concentration of arsenic reported for any given, unprocessed discrete sample within half a meter one to two feet of a grid point was estimated to vary on average by a factor of only two. The variability of lead concentrations in soil impacted by incinerator ash mixed with fill material was observed to be much higher, and on average just under one order of magnitude (Study Site B). Variability was highest in soils impacted by PCBs, presumably related to dumping of waste transformer oils. Concentrations of PCBs in discrete soil samples within and in the immediate vicinity of grid points varied on average by over two orders of magnitude.

These observations have important implications for the use of discrete sample data for site characterization, risk assessment and design of remedial actions. The data help explain the common occurrence of “false negatives” in environmental investigations. In such cases contaminated soil is excavated based on the results of initial discrete samples. The concentration of the contaminant in one or more confirmation samples collected from the walls and floor of the excavation surprisingly exceeds the cleanup level, however, even though discrete samples previously collected from the area were below the screening level. The results of the study demonstrate that this is most likely due to small-scale variability in contaminant concentrations in soil both above and below the target cleanup level and is an unavoidable artifact of discrete sampling. Failure to recognize this in the field leads to premature termination of site characterization activities and the need for repeated “step out” sampling following initial remedial efforts. It is also important to understand that cleanup levels, including the USEPA Regional Screening Levels, almost always apply to the *mean* concentration of the contaminant within a well-defined area, rather than to single points within that area.

Another problem inherent in the use of discrete soil sample data is the misinterpretation of seemingly isolated “hot spots” and “cold spots” as “outliers” within an area of otherwise more uniformly contaminated soil (i.e., based on a single or small number of sample points). In many if not most cases the outlier data more likely reflect random variability of the contaminant in soil at the scale of a single, discrete sample, rather than actual, mappable areas of elevated contamination. The collection and testing of a second, independent set of discrete samples from the same area would yield a similar number of apparent “hot spots” and “cold spots” but they would be located in different places.

Random, small-scale variability of contaminants in soil also significantly hampers the reliability of isoconcentration maps for anything other than gross, large-scale screening purposes. Over interpretation of isoconcentration maps based on discrete soil sample data is rampant in environmental investigations. Algorithms used to generate the maps necessarily assume that the concentration assigned to a single point is representative of

that point and that a predictable trend in concentrations exists between points. Data from this study clearly demonstrate that such assumptions cannot be taken for granted. While large-scale patterns based on tight grids of sample points might indeed be real, random, small-scale variability around any single grid points negates use of contours for prediction of contamination concentrations at any given point in the area.

A high, small-scale variability of contaminant concentrations within a targeted exposure area can also hamper the use of discrete soil sample data to estimate mean contamination concentrations for use in a risk assessment. “Outlier” data of exceptionally high contaminant concentrations can hamper the ability of geostatistical methods to calculate a mean within a desirable level of precision. Rather than accept the inability of the sampling approach to meet project objectives, a common practice is to simply delete “outlier” data until the target precision can be met. This distorts and biases the representativeness of the remaining data and can underestimate the actual risk posed by the contamination.

The problem with traditional, discrete soil samples is ultimately quite simple – they are too small to adequately capture and represent random, small-scale variability of contaminant concentrations inherent in soil. Discrete soil samples have their place in the initial screening of sites to better designate Decision Units (DU) for the collection of Multi Increment[®] soil samples (MIS), as described in the HEER Office Technical Guidance Manual. (Multi Increment[®] is a registered trademark of EnviroStat, Inc.) Large sets of discrete samples could in theory be used to fully characterize a site. This would require that clear investigation objectives and decision statements be established prior to sample collection, that an adequate number of samples be systematically collected from a targeted area in an unbiased manner in accordance with Sampling Theory (i.e., appropriate sample mass, shape, size, etc.), and that samples be properly processed and subsampled for testing. Independent sets of field replicate samples would also be required to evaluate the precision of the sampling method.

Such a science-based and well-thought-out method of discrete sample collection is rarely if ever carried out. Geostatistical methods used to evaluate discrete sample data sets impose a false sense of precision on the results (e.g., 95% UCL), since they test only the precision of the method to estimate a mean for the data provided, and not the precision of the data to represent the area from which the samples were collected. Incremental sampling methodologies, in contrast, are specifically designed to acknowledge and address these inherent and insurmountable problems in traditional, discrete sampling methodologies.

Additional analysis of the data is provided in Part 2 of this study. The results of this study will be incorporated into updates of the HEER *Technical Guidance Manual* (HDOH 2008; see also HDOH 2011a). This study was also carried out in part to provide

a technical basis for the use of DU-MIS investigation approaches at PCB-contaminated sites that fall under the USEPA Toxic Substances Control Act (TSCA). Data from Study Site C clearly demonstrate that the use of discrete samples to characterize PCB-contaminated soil can cause the extent and magnitude of contamination to be significantly under estimated. Significant, small-scale variability also complicates estimation of a reliable mean concentration for targeted areas for comparison to risk-based screening levels and estimation of risk. These problems can most efficiently be overcome through the use of well-thought-out, DU-MIS investigation approaches at these sites for final, decision making purposes.

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Appendix 1: Laboratory reports (electronic only)

Appendix 2: XRF Analytical Reports (electronic only)

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1 INTRODUCTION

This study was carried out to investigate the cause of decision error associated with discrete soil sample data for three common soil contaminants, and illustrate how the use of Decision Unit and Multi Increment Sample (MIS) approaches can significantly reduce decision errors in environmental investigations. The study is presented in two parts. Part 1, described in this report, presents the results of field investigations of contaminant distribution variability within a single discrete sample and within the immediate vicinity of where the primary sample was collected. Results of investigations at three separate study sites are presented and compared. Part 2 will explore the causes of variability in discrete sample data in more detail and review implications for the characterization, risk assessment, and remediation of contaminated sites.

The field portion of the study presented below was designed to address three questions that field workers face as part of a site investigation that relies on discrete sample data for final decision making: 1) How different might the result be if the lab selected another random test portion of soil from the discrete sample submitted?, 2) How different might the result be if the discrete sample collection point was moved over a few inches or a few *feet*?, and 3) How many discrete sample points need to be collected and averaged to achieve a “representative” sample result for the area investigated?

These important questions are rarely asked and tested as a part of soil investigations utilizing discrete sampling methods at contaminated sites. In some cases, a second “duplicate” discrete sample may be co-located and compared with a primary sample to provide data on the precision of the field sampling methods, but such data is limited to examining precision within very closely spaced samples, and this data may still not necessarily be incorporated into the data evaluation. In addition, true lab sub-sampling replicates are oftentimes not conducted or taken into account when evaluating data quality. A high variability in the results is often and erroneously blamed on a data “outlier” or as a result of lab analysis error, and the highest reported concentration simply applied to that sample. The same may be true of splits of samples submitted to separate laboratories for comparison of data, with the laboratory reporting the highest concentration of the target contaminant assumed to be “right” and the other laboratory assumed to be “wrong.”

Published research on soil sampling and lab sub-sampling methods have documented a high degree of variability in soil contaminant data (up to several orders of magnitude) may occur when using discrete sample methods in the field or using discrete sampling for sub-sampling in the lab. This is especially true when low numbers of discrete samples are used to characterize contamination in a specific area or where the lab collects a test portion using just a small scoop from one area of a sample jar, tube, or bag. Highly variable data do not provide a representative estimate of the mean concentration of target contaminants in specific investigation areas (DUs) and are therefore subject to challenge by clients, peers, or in court.

Laboratories have developed or follow detailed test method SOPs and report quality control measures for analyses, and as a consequence analytical error (i.e. the amount of lab error after a test portion has been collected) for common contaminant analyses is typically quite low, usually about <20%. In contrast, initial lab sample processing procedures, and most notably unrepresentative lab sub-sampling methods, can lead to very significant errors in reported results. Protocols to reduce lab sample processing errors are oftentimes over-looked by environmental consultants when contracting laboratory services. In addition, representative lab sub-sampling protocols have generally not been included within USEPA test methods used by labs for soil contaminant analyses.

The issue of small-scale variability of contaminant concentrations in soil is well studied for explosives related contamination (e.g., Ramsey and Hewitt 2005), and the USEPA lab method for explosives analyses includes an Appendix detailing the use of representative (MIS) procedures for both field sample collection and lab sub-sampling (Method 8330B). Research on contaminant variability and representative sampling or sub-sampling issues are less common for other types of soil contaminants. Hadley and Bruce (2013) provide a good overview of this issue and the risk of decision error when relying on discrete sample data to characterize, assess and ultimately remediate an area of contaminated soil. Such problems are exemplified in the field by the need for repeated yet often inconclusive sampling efforts, confusion over seemingly isolated “hot spots” and “cold spots,” questionable elimination of apparent “outlier” data for estimation of contaminant means and use in risk assessments, failed confirmation samples following remedial actions, and the discovery of additional contamination at sites where characterization and remedial actions were assumed to have been completed.

These problems are well known and many site investigators are now switching to “Decision Unit (DU)” and “Multi Increment (MI)[®]” or “incremental” sampling approaches to address uncertainty in traditional, discrete sample data (e.g., ITRC 2012). Hawai‘i began making the switch in 2004 and was the first (and currently only) state to publish comprehensive guidance on “DU-MIS” site investigation approaches (HDOH 2008; 2011a), although discrete sample data are sometimes still used to help guide the design of these investigations. Incremental samples are sometimes described as “structured composites” that are collected from well-thought-out, targeted areas (i.e., DUs) and processed at the laboratory in a manner that produces representative and reproducible data (Hadley and Bruce 2013). The nature and advantages of incremental sampling approaches will be discussed in more detail in Part 2 of this study.

In addition to the well-documented sampling work involving explosives-related contamination, anecdotal evidence and small studies of significant heterogeneity both within and in the vicinity of discrete soil samples are abundant (e.g., USEPA 1989, 1990, USEPA 2003). However, detailed field studies identifying the nature and magnitude of discrete sample variability for a number of soil contaminants are less common. The study presented in this report is intended to help fill this gap. Three sites with different soil contaminants were selected to investigate the nature and magnitude of contaminant variability both within individual, discrete samples (“intra-

sample” variability) and between closely spaced samples around individual grid points (“inter-sample” variability). Section 2 of this report describes the selection process and the background of each site. Sample collection and analysis procedures are described in Section 3. Resulting data for each of the study sites are presented and summarized in Section 4. Section 5 presents a comparison of data between study sites and includes an initial discussion of the likely nature of the differences observed. Section 6 of the report concludes with preliminary thoughts regarding implications of the study results in terms of the reliability of discrete sample data for site characterization, risk assessment and design of remedial actions for contaminated soil.

2 SELECTION OF STUDY SITES

Three sites, two on Oʻahu and one on the island of Hawaiʻi, were selected for an investigation of small-scale, discrete sample variability. Criteria for selection of a site in the study included: 1) Existing data that indicated the presence of exposed, contaminated soil; 2) Anticipated low, moderate or high small-scale variability; and 3) An access agreement was obtained for the collection of samples. Although it could not be confirmed prior to the actual collection and testing of samples, an intentional effort was made to select sites that spanned a range of anticipated variability, as predicted by the chemical type, how the chemical was likely released on the site, or as was apparent in existing data. A brief summary of each site is presented below. The locations of the study sites are depicted in Figure 2-1.

2.1 SITE A: WAILOA STATE PARK, HILO, HAWAIʻI

Study Site A is an area of arsenic-contaminated soil within the 132-acre, Wailoa River State Recreation Area (Wailoa State Park) on the island of Hawaiʻi. The location of the site is depicted in Figure 2-2.

The park is centered around Waiakea pond, a stream- and spring-fed body of fresh to brackish water that serves as an important estuary and ecological habitat. Historical operations suspected to be tied to the arsenic contamination include a Canec fiber-treatment factory and a sugar mill, both formerly located on the mauka/upper (southern) side of the pond (see Bernard and Orcutt 1983). The Hawaiian Cane Products plant in Hilo produced arsenic-infused (arsenic trioxide) wallboard and building material from sugarcane bagasse from the 1930s through the 1960s, referred to as “Canec.” The arsenic served as a termiticide and preservative. Wastewater from the plant is believed to have been discharged directly into Waiakea pond. Both the sediment in the pond and the soil immediately adjacent to some areas of the pond are known to be contaminated with arsenic (e.g., Hallacher et al., 1985; Silvius et. al 2005; HDOH 2013). The bioavailability of the arsenic in soil from this area is known to be exceptionally low (e.g., <10%; Roberts et. al 2007) and in most areas is not believed to pose a significant risk to human health. Potential impacts on aquatic organisms and other ecological receptors are under current investigation. Contamination of upland soils could be due to past disposal of pond dredge spoils and/or direct discharges of wastewater from the plant. Arsenic contaminated sediment in the pond could also be associated with runoff from former sugarcane fields in the watershed that drains to the pond. Contribution of arsenic contamination from the former sugar mill located on the edge of the pond is also likely (e.g., mud from cane washing activities), although this has not been investigated in detail.

An open, grass-covered area in the northeastern area of Wailoa State Park was selected for sample collection (see Figure 2-3; Photo 2-1). Prescreening of surface soil in the area with a portable XRF indicated arsenic concentrations well over 100 mg/kg and confirmed that the area was suitable for inclusion in the study (Photo 2-2). A grid of twenty four points at thirty-foot spacing was designated within a 150' x 90' area (Figure 2-4).

2.2 SITE B: FORMER WAIPAHAU INCINERATOR, WAIPAHAU, O'AHU

Study Site B is an area of lead-contaminated soil at the former Waipahu incinerator site on the island of O'ahu. The location of the approximately ten-acre site is depicted in Figure 2-5. The incinerator operated from the early 1970s through the mid 1990s and generated 60 to 120 tons of ash per day (AMEC 2009). Most of the ash was transferred to an adjacent landfill, but ash was also mixed with fill material placed across the incinerator site. Previous investigations identified lead-contaminated soil throughout the property and extending to a depth of ten feet or more in some areas (AMEC 2013). Lead was reported at concentrations up to 1,800 mg/kg in Multi Increment (MI) samples collected from surface soils.

Access to open areas of the site at the time of the study was hampered by thick vegetation. A 50' by 30' area was ultimately selected for sample collection and cleared of tall grass prior to field work (Figure 2-6; Photo 2-3). Prescreening of surface soil in the area with a field XRF indicated concentrations of lead in excess of 200 mg/kg and confirmed that the area was suitable for inclusion in the study. A grid of twenty four points at ten-foot spacing was designated within a 50' x 30' area (Figure 2-7).

2.3 SITE C: FORMER VOICE OF AMERICA BROADCASTING STATION, MA'ILI, O'AHU

Study Site C is an area of PCB-contaminated soil at a former Voice of America broadcasting station in Ma'ili, on the island of O'ahu (Figure 2-8). The 93-acre site operated as an antenna relay station from the 1940s through the 1970s. Equipment and buildings were progressively removed from the site in the 1980s and 1990s.

Site investigations in 2009 and 2011 identified PCB impacts to soil in MI samples in a four-acre area adjacent to the former transmitter station (Element Environmental 2011). Followup discrete samples were collected around the former transmitter station at a grid spacing of ten-feet, in an attempt to identify areas of higher contamination and assist in future, more focused MI sample collection. Samples were tested using field immunoassay kits, with splits of some samples submitted to a laboratory for analysis by GC/MS Method 8082. The sample data indicated concentrations of PCBs in soil (at the scale of a ten-gram, discrete sample subsample) greater than 50 mg/kg at random locations throughout the area, with PCB concentrations greater than 1,000 mg/kg reported for some samples. The data suggested significant, small-scale variability of PCB concentrations in soil at the site, making it a good candidate for inclusion in the study.

A 100' by 60' area was selected for sample collection (Figure 2-9; Photo 2-4). The eastern portion of the area was anticipated to exhibit comparatively higher concentrations of PCBs in comparison to the western portion of the area. The area was anticipated to include a mix of high to lower PCB concentrations based on previous MIS and discrete sample data. A grid of twenty four points at twenty-foot spacing was designated within the area (Figure 2-10).

3 SAMPLE COLLECTION

3.1 SAMPLING DESIGN AND COLLECTION METHOD

Samples were collected by HEER office staff and in some cases with the assistance of local consultants. Discrete samples from Study Site A in Hilo were collected on August 22, 2013. Multi Increment samples were collected from the same area on February 7, 2014. Discrete and MI Samples were collected from Study Site B in Waipahu on February 27, 2014. Samples were collected from Study Site C in Ma'ili on March 5, 2014.

Five discrete soil samples were collected at each grid point at Study Site A (arsenic) and Study Site B (lead) – one sample from each corner of a three-foot box around each point and one sample from the center (Photos 3-1 through 3-5). The top two inches of soil below any grass and organic debris layer was targeted for sample collection. A trowel was used to collect samples, with care taken to collect equal amounts of soil across the targeted depth and minimize vertical bias. An approximately 200g to 300g discrete sample was collected from each corner grid point location, with each sample placed in separate, one-quart, zip-lock freezer bags (grid point Samples B, C, D and E; total 96 samples).

A fifth, 400g to 500g discrete sample was collected from the center of each grid point and placed in a rigid, eight-ounce, plastic container, with care taken to minimize disturbance of the sample (Sample A; total 24 samples). These samples were used to evaluate intra-sample variability of contaminant concentrations at the scale of the mass typically tested by a laboratory (e.g., one gram for metals). As described in the following “Analysis” section, this was accomplished by testing ten separate locations within the sample through the use of a portable XRF.

All discrete samples from the study site were then submitted to the laboratory for processing and analysis (total 120 samples per site). Processing was carried out in the same manner as done for MI samples (i.e., sample air dried, sieved to <2mm and subsampled, with ten-gram subsamples collected for analysis; refer to HDOH 2008).

A similar sample collection approach was employed at Study Site C (PCBs; Photos 3-6 and 3-7). Two samples were collected from the center of the grid point, however. A 200g to 300g sample was collected in the same manner as carried out for the corner samples and similarly placed in a zip-lock bag. This sample was included with the four corner samples and processed and tested for PCBs in the same manner as described above for the arsenic and lead sites (total 120 samples). The “Results” section data for these samples are used to evaluate small-scale, inter-sample variability around each grid point. A second, 400g to 500g sample was collected from a 10cm radius area near the center of the grid point but placed in ten, separate four-ounce jars with 40g to 50g of soil per jar (total 24 sets of ten jars each per grid point). Each jar represents a subsample of the total, bulk sample collected at the sampling point. The subsamples were submitted for analysis *in the absence of* standard incremental sample processing, although

the lab attempted to “homogenize” each sample using standard, discrete sample protocol prior to removing a ten gram mass for analysis. As discussed below, the resulting data are used to evaluate intra-sample variability of PCB concentrations at the scale of a laboratory test portion (e.g., ten grams).

A hand trowel was again used to collect samples from the corner and center of each grid point that were to be processed prior to analysis. Stainless steel spoons were used to collect subsamples from the bulk sample area at the center of each grid point. Each subsample was analyzed at the laboratory without processing. Sampling equipment was decontaminated (triple washed) between individual discrete samples from grid corners as well as between subsamples of samples collected from the center of each grid point.

Triplicate MI samples were also collected across each grid area from the sample targeted depth and area (Photo 3-8). Increments were collected through use of a sampling core. Fifty-four increment MI samples were collected from Study Site A and Study Site B. Sixty-increment MI samples were collected from Study Site C. Samples were collected in a systematic, random fashion.

Center grid point samples (“A” samples) from Study Site A (arsenic) and Study Site B (lead) to be evaluated for intra-sample variability using a portable XRF were delivered to Geotek, Hawai‘i in Waipahu (total 24 samples per site). The remaining samples (Samples B-E) were delivered to Test America, Honolulu for laboratory processing and analysis (total 96 samples per site). Samples initially delivered to Geotek, Hawai‘i were delivered to Test America by Geotek, Hawai‘i for inclusion with the other samples once XRF testing was complete (combined total 120 samples per site).

Samples collected from Study Site C (PCBs) were submitted to Test America as a single delivery. Ten subsamples per grid point in four-ounce jars were submitted for analysis without additional processing, mimicking the standard laboratory practice (total 240 subsamples and jars). Five additional samples per point (one center and four corner samples) per grid point were submitted for MIS processing and analysis (total 120 samples).

Triplicate, Multi Increment samples collected from each study site were delivered to Test America following the completion of field work for MIS processing and analysis (total nine samples).

3.2 SAMPLE PROCESSING AND ANALYSIS

3.2.1 PORTABLE XRF ANALYSIS

Undisturbed samples collected from Study Site A and Study Site B were analyzed at Geotek Hawai‘i using a field portable X-ray fluorescence detector (XRF) in a manner similar to EPA method 6200 (USEPA 2007a; refer to Appendix 2). An Olympus Delta 2000 standard XRF with a four watt x-ray tube and silicon drift detector was utilized. Field calibration standards, blanks

and spikes were used for QA/QC measures. The instrument beam width is approximately one centimeter in diameter. The effective penetration depth of the beam for soil is estimated to be one centimeter, for a total soil mass tested of approximately one gram. This is similar to the mass of soil traditionally tested for metals at commercial labs based on use USEPA lab methods, including Method 6010B (see USEPA 1996, 2007b).

The instrument was calibrated daily using a 318 stainless steel coin as per manufacturer specs. Following the calibration a silicon blank was analyzed to confirm negative control. The field matrix spike was analyzed to confirm positive control and a NIST standard reference material, SRM2711a, was confirmed twice daily at the beginning and end of each batch. Method precision was evaluated by taking multiple readings from the same sample location.

Testing was carried out by opening the top of the sample container and placing a thin plastic sheet marked with five evenly spaced sample locations directly on the soil (Photo 3-9). Care was taken to avoid large particles (e.g., >2mm) in samples. Measurements were taken at each of the five marks. Afterwards, the sample was turned over, pressed out of the container onto a clean plastic sheet and the process was repeated on the bottom side of the sample.

Soil at Study site A was visibly moist during sample collection due to recent rain. Samples were not air-dried prior to testing. Data were corrected for moisture afterwards, however, and reported in dry weight (average moisture content 50%). Comparison of moisture-corrected data for previous samples with data after the samples were dried indicated minimal interference with moisture on XRF precision. Samples from Study Site B were not significantly moist upon collection (moisture estimated to be <10%). The XRF data are considered to reasonably approximate dry weight.

3.2.2 LABORATORY ANALYSIS

Samples were submitted to Test America laboratory in Honolulu for processing and analysis. Samples were dried, sieved and subsampled for the collection of subsamples in accordance with the HEER Office Technical Guidance Manual (HDOH 2008).

Grain size analysis was carried out on the center sample from each grid point (“A” samples”) using Method D422 (ASTM 1998). In the case of Study Site C, grain size analysis was carried out on the combined, subsamples 1-5 of the discrete sample that was used to evaluate intra-sample variability. Grain sizes are defined as follows:

Particle Classification	Definition
Gravel	Passing 75mm sieve and retained on No. 4 sieve (4.75mm)
Sand	Passing No. 4 sieve and retained on No. 200 sieve (0.75µm)
Coarse Sand	Passing No. 4 sieve and retained on No. 10 sieve (2mm)
Medium Sand	Passing No. 10 sieve and retained on No. 40 sieve (425µm)
Fine Sand	Passing No. 40 sieve and retained on No. 200 sieve (75µm)
Silt	<75µm to ≥5µm.
Clay	<5µm.

Arsenic (Study Site A) and lead (Study Site B) analyses were carried out using Method 6010B. A ten-gram mass of soil was tested in accordance with the HEER office Technical Guidance Manual, in order to further minimize the effects of fundamental error. Note that this contrasts with the recommendation to test only one-gram of soil in the USEPA lab method; see USEPA 1996b. Copper, iron, nickel and zinc were also reported in order to provide a comparison to XRF data. Samples from Study Site C were tested for PCBs using Method 8082. A ten-gram mass of soil was tested, in accordance with standard method recommendations.

4 RESULTS

Data from the study are presented in a series of tables that summarize the following information:

- Grain size distribution;
- Intra-sample variability (i.e., within single samples);
- Inter-sample variability (i.e., around individual grid points);
- Combined intra- and inter-sample variability.

The data are briefly discussed below and evaluated in more detail in the Data Interpretation section of the report.

The Relative Percent Difference (RPD) between maximum- and minimum-reported concentrations relative to the mean is calculated for intra-sample data at each grid point in the study areas. The hypothetical range of discrete sample concentrations within 0.5m of a grid point is estimated by adjustment of processed sample data (assumed to represent the mean for that sample) downwards and upwards RPDs calculated for the intra-sample data set from same grid point (Figure 4-1). This is primarily for illustration purposes only and the accuracy of estimated range is uncertain. The collection of additional, discrete samples around a grid point would likely indicate a broader range of variability than that captured in this study. The implications of total, estimated variability around grid points is discussed in more detail in the Data Interpretation section of the report and in Part 2 of the study.

4.1 SITE A

Table 4-1 presents particle-size distribution data for the center sample collected at each of the twenty-four grid points for Study Site A. The average grain size distribution is summarized in Figure 4-2. Soils at the site are characterized by dark brown, silty, clayey, fine sands with silt and minimal coarse material. The soils are either native andisol or sediment dredged from the adjacent Waiakea pond in the past and placed in the upland park area.

Table 4-2 presents arsenic data for XRF readings (ten) carried out on the undisturbed, discrete sample collected from the center of the twenty-four grid points at Study Site A. These data reflect intra-sample variability data for the study site. Table 4-3 presents a summary of the data for each grid point, in terms of the lowest-reported and maximum-reported concentration of arsenic from the XRF readings and the ratio of the maximum to minimum concentrations. The mean concentration of the XRF readings for arsenic in the sample and the relative standard deviation of the mean are noted. Relative Percent Differences (RPDs) are calculated for the maximum-reported concentration of arsenic relative to the minimum-reported concentration and the minimum- and maximum-reported concentrations of arsenic relative to the mean for each group of sample data. The latter are used to estimate the total, variability of arsenic concentrations in any given, random discrete soil sample collected and tested around an individual grid point (see below).

Table 4-4 presents arsenic data for each of the five, discrete soil samples collected around designated grid points of Study Site A and processed following MIS protocol prior to subsampling and analysis. These data are used to evaluate small-scale, inter-sample variability at the study site.

Table 4-5 presents a comparison of the mean concentration of arsenic in discrete Samples A as measured using the portable XRF (see Table 4-2) to the concentration of arsenic reported using Method 6010B after the samples were processed at the laboratory. Although not a primary focus of this study, it is worth noting that the total concentration of arsenic reported using the portable XRF is consistently higher than that reported by extraction-based Method 6010B (average +31%). This is to be expected, since the XRF is not influenced by the efficiency of the extraction and is more likely to report a true, total concentration of the metal in the sample. The same observation was made for reported concentrations of copper, iron and zinc in the samples, with the total iron especially under-reported by Method 6010B (see Table 4-5; average +54%, 64%, +38%, respectively). The XRF mean also reflects analysis of ten grams of soil per sample (i.e., ten analyses per sample), whereas the 6010B data only reflects testing of one gram. Sampling theory predicts that the mean concentration of a chemical estimated for a sample will increase and approach the true mean with increasing mass analyzed, as “outlier,” high-concentration “nuggets” of soil are incorporated into the analysis (Pitard 1993, 2009). Low recoverability of matrix spikes for arsenic in the iron-rich, volcanic soils of Hawai‘i suggests that the primary bias is due to the test method, however.

Table 4-6 presents a summary of data for processed samples at each grid point in terms of the lowest- and maximum-reported concentration of arsenic, as well as the mean of the reported concentrations and the ratio of the maximum to minimum concentration reported. The Relative Percent Difference (RPD) between maximum- and minimum-reported concentrations reported for intra-sample data at each grid point is also noted, as is the Standard Deviation (SD) and Relative Standard Deviation (RSD) of the intra-sample data. Table 4-7 provides a summary of the combined, intra- and inter-sample variability of arsenic concentrations for discrete samples collected from each grid point at Study Site A. .

4.2 SITE B

Table 4-8 presents particle-size distribution data for the center sample collected at each of the twenty-four grid points for Study Site B. The average grain size distribution is summarized in Figure 4-3. Soils at the site are characterized by grayish-yellow to yellowish orange sand to silty sand with an average of 25% gravel and coarse sand. The soils represent fill material placed around the property during construction and operation of the former incinerator. The lab reported that the mass of soil provided was inadequate to carry out a complete, grain-size analysis in accordance with ASTM Method D422 (up to one-kilogram or greater soil mass required for mixed, gravelly soils). The data provided reflect observations made in the field, however, and are considered to be reasonably representative for the purposes of this study.

Table 4-9 presents lead data for XRF readings (ten) carried out on the undisturbed, discrete sample collected from the center of the twenty-four grid points at Study Site B. These data reflect intra-sample variability data for the study site. Table 4-10 presents a summary of the data for each grid point, in terms of the lowest-reported and maximum-reported concentration of lead from the XRF readings and the ratio of the maximum to minimum concentration reported. The mean concentration of the XRF readings for lead in the sample and the relative standard deviation of the mean are noted. Relative Percent Differences (RPDs) are calculated for the maximum-reported concentration of arsenic relative to the minimum-reported concentration and the minimum- and maximum-reported concentrations of arsenic relative to the mean. The latter are again used to estimate the total, variability of lead concentrations in any given, random discrete soil sample collected and tested around an individual grid point (see below).

Table 4-11 presents lead data for each of the five, discrete soil samples collected around designated grid points of Study Site B and processed following MIS protocol prior to subsampling and analysis. These data are used to evaluate small-scale, inter-sample variability at the study site.

Table 4-12 presents a comparison of the mean concentration of lead in discrete Samples A as measured using the portable XRF (see Table 4-9) to the concentration of lead reported using Method 6010B after the samples were processed at the laboratory. The results are more variable in comparison to data for Study Site A. This is to be expected, given the overall increase in metal concentration variability observed at Study Site B (e.g., compare Table 4-4 for Study Site A to Table 4-11). In contrast to arsenic in Study Site A, however, the total concentration of lead reported using the portable XRF is on average somewhat lower than reported by extraction-based Method 6010B (average -6.8%). This is primarily due to two factors: 1) An increased laboratory extraction efficiency of lead in comparison to other metals and 2) A reduction in XRF readings due to moisture in the samples (moisture estimated to be 5-10%). Although the total mass of soil tested was identical (10g), data for the processed sample represents testing of soil particles from more locations within the original soil. An increase in the reported concentration of a contaminant is expected as scattered, higher-concentration clusters of soil particles are included in the subsamples for analysis.

Table 4-13 presents a summary of data for processed samples at each grid point in terms of the lowest- and maximum-reported concentration of lead, as well as the mean of the reported concentrations and the ratio of the maximum to minimum concentrations. The Relative Percent Difference (RPD) between maximum- and minimum-reported concentrations reported for intra-sample data at each grid point is also noted, as is the Standard Deviation (SD) and Relative Standard Deviation (RSD) of the intra-sample data.

Table 4-14 provides a summary of the combined, intra- and inter-sample variability of lead concentrations for discrete samples collected from each grid point at Study Site B. This includes the estimated total range of minimum and maximum lead concentrations for any given,

hypothetical discrete sample collected within 0.5m of a grid point, again based on adjustment of measured concentration for processed sample downwards and upwards with respect to mean RPD measured for intra-sample data set from same grid point (see Table 4-10). Total, estimated variability around grid points is discussed in more detail in the Data Interpretation section of the report.

4.3 SITE C

Table 4-15 presents particle-size distribution data for the center sample collected at each of the twenty-four grid points for Study Site C. Three distinct soil types were observed at the site (see Figure 2-10). Soils in the western third of the study area characterized by native, black to brownish black, clayey, silty sand to sandy silt with minimal coarse material (mollisol). Soil in the eastern third of the study area is characterized by dark, reddish-brown to grayish-yellow, gravely, silty sand that represents imported fill consisting of mixed, volcanic soil and cinder. An area of coralline gravel and fill material is present to the immediate east of the area samples (see white patches in 2-10). The middle portion of the study site is characterized by a mixture of native soil and fill material. The average grain size distributions in the native soil and fill are summarized in Figures 4-4 and 4-5. The average percentage of medium to coarse sand and gravel is significant higher in the fill material (56%) than the native soil (17%). The average percentage of fine sand, silt and clay is similarly much higher in the native soil (83%) than the fill material (44%).

Table 4-16 presents PCB data for separate subsamples (ten) of the undisturbed, discrete sample collected from the center of the twenty-four grid points at Study Site C. These data reflect intra-sample variability data for the study site. Table 4-17 presents a summary of the data for each grid point, in terms of the lowest-reported and maximum-reported concentration of PCBs in subsamples and the ratio of the maximum to minimum concentration reported. The mean concentration of the intra-sample data for PCBs in each sample and the relative standard deviation of the mean are also presented. Relative Percent Differences (RPDs) are again presented for the maximum-reported concentration of PCBs relative to the minimum-reported concentration and the minimum- and maximum-reported concentrations of PCBs relative to the mean. The latter are used to estimate the total, variability of PCBs concentrations in any given, random discrete soil sample collected and tested around an individual grid point (see below).

Table 4-18 presents PCBs data for each of the five, discrete soil samples collected around designated grid points of Study Site C and processed following MIS protocol prior to subsampling and analysis. These data are used to evaluate small-scale, inter-sample variability at the study site. Table 4-19 presents a summary of the data for each grid point, in terms of the lowest- and maximum-reported concentration of PCBs, as well as the mean of the reported concentrations and the ratio of the maximum to minimum concentrations. The Relative Percent Difference (RPD) between maximum- and minimum-reported concentrations for intra-sample

data at each grid point is also noted, as is the Standard Deviation (SD) and Relative Standard Deviation (RSD) of the intra-sample data.

Table 4-20 provides a summary of the combined, intra- and inter-sample variability of PCBs concentrations for discrete samples collected from each grid point at Study Site C. As done for the other study sites, this includes estimated total range of minimum and maximum PCB concentrations for any given, hypothetical discrete sample collected within 0.5m of a grid point, again based on adjustment of measured concentration for processed sample downwards and upwards with respect to mean RPD measured for intra-sample data set from same grid point (see Table 4-17). Total, estimated variability around grid points is discussed in more detail in the following section.

5 DATA SUMMARY AND INTERPRETATION

Table 5-1 presents the average, estimated, total relative variability of contaminant concentrations in discrete soil samples around individual grid points at each of the study sites. As discussed earlier in the report, the term “variability” is for the purposes of this discussion used in a very general sense, and intended to simply reflect the difference (e.g., Relative Percent Difference) between estimated minimum and maximum concentrations and the mean.

A summary of the variability of contaminant concentrations at each scale is depicted graphically in Figure 5-1. The values should be considered to represent the minimum variability present. It is unlikely that the minimum and maximum contaminant concentrations reported represent the true range of variability present in the samples and around each grid point, given the relatively small fraction of soil tested. Testing of additional subsamples from unprocessed, individual samples or additional, processed samples within a one- to two-foot radius of individual grid points would likely identify even greater variability.

A basic evaluation of variability both within and between co-located samples is provided below. In combination, these observations are used to assess the nature of small-scale variability in contaminant concentrations around individual grid points at the scale of a traditional, discrete sample laboratory test portion. A more detailed discussion of the origins of this variability in terms of sampling theory will be included in Part 2 of this study.

5.1 INTRA-SAMPLE VARIABILITY

5.1.1 SUMMARY OF STUDY SITE DATA

The variability of contaminant concentrations within a single discrete sample is clearly different between Study Sites A, B and C, even though it is unpredictable at any given point within a site (see Table 5-1; see also Tables 4-3, 4-10 and 4-17). Data are right-skewed, with the mean max:min ratio significantly higher than the median ratio, especially for Study Sites B and C. The median is therefore used for general discussion purposes.

The variability of intra-sample, XRF data for arsenic at Study Site A is comparatively low, with a median max:min ratio of 1.4. The range of min-max ratios reported for samples is likewise very tight, with a maximum ratio of 2.5 calculated for one sample. In other words, the concentration of arsenic in randomly tested, one-gram subsamples of soil from a single, discrete sample could vary by a factor of at least 2.5. The average, relative standard deviation (RSD) of the intra-sample data is just 12%, with a range of 5-30%.

The low variability concentrations between individual XRF readings for a given sample from Study Site A suggests that the arsenic is present as finely disseminated and relatively evenly distributed particles with the soil. This has indeed been determined previously by detailed studies of arsenic geochemistry for soils in the area (Cutler 2011; Cutler et al. 2006, 2013). Arsenic is concentrated in iron-hydroxide particles in the finest fractions of the soil (<74µm

fraction). This is not surprising given the iron-rich nature of the volcanic soils, and the fact that the arsenic is known to be related to either discharge of contaminated wastewater from a nearby Canec plant or runoff from nearby, former sugarcane fields where water-based arsenical pesticides were used for weed control.

The variability of lead concentrations within individual soil samples at Study Site B is distinctly higher, with a median of max:min ratio of 3.5 and a maximum of 14.5. The RSDs for the intra-sample data are likewise higher, with an average of 40% and a range of 20-96%. Lead in the soil is known to be related to mixing of incinerator ash in fill material. The heterogeneous nature of lead at the scale of a one-gram subsample most likely reflects random, small-scale variations in the amount of ash in any given mass of fill material. Pockets of light-colored material a few millimeters across within the soil were evident in the field. Intentionally targeting these areas with a portable XRF yielded notably higher concentrations of lead than the surrounding soil (e.g., up to 10X), suggesting that they may be concentrated pockets of ash.

Intra-sample variability of contaminant concentrations is greatest for PCBs at Study Site C, with a median max:min ratio of 6.9 for native soils and 12 for fill soils. An example of both intra- and inter-sample variability at the site is depicted in Figure 5-2. The min-max ratios reported for the intra-sample data is also broad, with a ratio of 116 calculated for one sample. The average RSD of intra-sample data is 72%, with a range of 17-277%. The fact that the concentration of PCBs at the scale of a standard, ten-gram lab test portion can range by over two orders of magnitude within a single discrete sample has significant implications for the reliability of the data in decision making.

5.1.2 SUSPECT PCB-INFUSED NUGGETS AT STUDY SITE C

Presence of and Formation of Nuggets

It is hypothesized that the high variability of PCB concentrations within single, discrete samples and between collocated samples at Study Site C is tied to the presence of small, PCB-infused “tar balls” or nuggets in the soil. Infiltration of a liquid into soil is governed by two forces, gravity and capillary action (after Goodman 2001; Santamarina 2001; Murray and Sivakumar, 2010). The molecules of the liquid are initially drawn to each other by cohesive forces, forming a rounded droplet. The liquid inside the droplet is under positive pressure in comparison to the surrounding air.

The surface of the droplet and soil particles it comes in contact with are attracted by adhesive (van der Waals) “capillary” forces. Soil particles initially become bound to the surface of the liquid, coating and forming a rim around the droplet. Gravity and capillary forces gradually overwhelm cohesive forces within the droplet and begin to draw the droplet into the soil. Eventually a state is reached where the droplet is drawn entirely into the soil, creating a saturated aggregate. Remaining cohesive forces within the liquid cause the aggregate to separate from the surrounding particles and form a rounded “nugget,” with a final coat of fine soil particles adhered to the outer surface.

An example of droplet formation and infiltration into soil is depicted in Figure 5-3 and Figure 5-4. Olive oil was dripped onto dry flour. Streaks of oil immediately drew together to form rounded droplets that rose high above the flour, as recorded by tracks observable in the flour in Figure 5-3. Over a few minutes time, the oil was slowly drawn into the flour, forming distinct clumps of oil-saturated flour (see Figure 5-4). Note the distinct, thin rim around the aggregate in photograph. Aggregates subsequently sieved from the flour represent remnants of olive oil droplets originally released to the flour (Figure 5-5).

Photos of soil sample VOA-12 (8) from Grid Point 12 are presented in Figure 5-6. This was one of ten subsamples tested from a discrete sample collected from the grid point. The laboratory reported a concentration of PCBs in the sample of 11,000 mg/kg (see Table 16 in Part 1). Dark, rounded, millimeter-size clumps of soil are visible in the most heavily impacted areas of Study Site C. Unlike rock fragments, these clumps crumbled when lightly pressed with a knife (see Figure 5-6). The clumps were also very granular and clearly not clay. This is observable using higher magnification under a microscope, as depicted in Figure 5-7. (Note that this is a different clump than shown in Figure 5-5.) Note the distinct, thin, light-colored rim around the perimeter of the clump, with a coating of darker, granular material adhered to the outside. It is feasible that the mineral oil into which the PCBs were dissolved might slowly degrade overtime due to and bacterial action and other mechanisms, progressively increasing the relative concentration of PCBs in the nugget. Some larger grains of rock particles within the soil appeared to be covered with a dark, granular material that could similarly represent a coating of PCB oil. Whether or not this is indeed the case can only be confirmed by laboratory analysis of individual, suspect clumps. Attempting to do so was beyond the scope of this study, however.

Dramatic differences of PCBs concentrations in ten gram subsamples of soil within a single sample and between co-located samples are thought to reflect small-scale, random variability in the distribution of small nuggets of PCB-infused soil within the samples. Patterns of PCB contamination in soil might look similar to spatter paintings, where the paint also beads upon release to form isolated streaks and droplets on canvas (Figure 5-8). Spills of liquids can also be expected to follow small-scale variations in surface topography, leading to patterns like the one illustrated in Figure 5-9 for a spill of milk by a roadside. Problems in attempting to characterize these patterns of contamination in soil using small numbers of randomly located discrete samples when the contaminant cannot be visually seen are obvious, including the risk of false negatives. This issue will be discussed in more detail in Part 2 of the study.

Intra-sample variability of PCB concentrations at Study Site C is also clearly related to a small-scale heterogeneity of soil types within a 10cm radius from which the discrete soil samples were collected. Figure 5-10 depicts two distinct soil types encountered within a discrete sample collected from Grid Point 12 at Study Site C. The subsample on the left is dominated by coralline soil with little clay organic material. A PCB concentration of 270 mg/kg was reported for a 10g mass of soil tested from this subsample. The subsample on the right is dominated by reddish brown soil with moderate amounts of silt and clay. A PCB concentration of 11,000

mg/kg was reported for this subsample. A small patch of white material in the vicinity of Grid Point 12 is apparent in Figure 2-10. Significant patches of coralline material were not noticeable within the study area at the time samples were collected, however, due in part to the thick, vegetative cover.

Comparison of PCB versus TPH Data

Total Petroleum Hydrocarbons (TPH) data for samples from Study Site C appear to verify the presence of PCB-infused nuggets of degraded transformer oil and soil particles at the site. Field subsamples 6 through 10 of the sample sets used to test intra-sample variability around each grid point were combined and tested for TPH. The resulting samples were air-dried, sieved and subsampled by the laboratory for testing using MIS methodologies. The extract from a single, 30g subsample collected from each processed sample was analyzed for Diesel Range Organics (C10-C28), Residual Fuel Organics (C29-C40), heavy hydrocarbon compounds (C41-C44) and total Extractable Fuel Hydrocarbons (C10-C44). Holding times for the samples were exceeded (see Appendix 1). Loss of TPH due to volatilization and/or biodegradation during sample storage and processing can reasonably be assumed to be minimal, however, given that the samples were collected from exposed surface soils affected by spills that had occurred several decades in the past.

A summary of PCB data for the sample sets is presented in Table 5-2 (see also Table 4-16). A combined summary of PCB and TPH data for the same sample sets is presented in Table 5-3. Laboratory reports for TPH analyses, including chromatograms, are included in Appendix 1.

The TPH compounds primarily fall within the range of C20 to C40. As depicted in Figure 5-11, two distinct groups of TPH compounds seem apparent in several of the chromatograms, one group from approximately C20 to C28 and a second grouping from C28 to approximately C40. The first grouping is interpreted to reflect degraded transformer oil, initially comprised of C12-C28 compounds but with lighter end compounds preferentially lost over time due to volatilization and biodegradation (EPRI 1998). The second grouping is interpreted to reflect heavier waste oil, for example from auto engines or generators, and potentially fragments of asphalt from adjacent, former driveway to the radio facility.

Figure 5-12a presents a graph of TPH, measured as C10-C28, vs PCB data. A strong correlation of increasing TPH with increasing PCB is apparent in the data (R^2 value 0.93; see also Table 5-3). This supports the hypothesis that PCBs are associated with nuggets of degraded transformer oil. The ratio of TPH:PCB approaches 1:1 in some samples, implying that tarry matrix of the hypothesized nuggets of degraded transformer oil might be comprised of up to 50% PCBs if it could be analyzed separately from soil particles (see Table 5-3). The trend is somewhat weaker for samples with concentrations of PCBs <100 mg/kg (Figure 5-12b). This is primarily due to two “outlier” samples, with relatively high concentrations of TPH in comparison to PCBs (samples VOA-2 and VOA-11; see Table 5-3). A reasonably strong R^2 value of 0.91 is generated when these two samples are excluded. The concentration of PCBs in both outlier

samples is moderately high (11 mg/kg and 22 mg/kg, respectively). The discrepancy could be due to additional lighter-end, TPH in the soil not related to releases of transformer oil (e.g., waste auto engine oil) or error related to testing of separate subsamples for TPH and PCBs.

5.1.3 VARIABILITY AND PARTICLE SIZE DISTRIBUTION

Variability of particle size distribution in soil (e.g., clay, silt, sand and gravel) can also affect variability in contaminant concentrations within a soil sample (Pitard 1993, 2009; Minnitt 2007). Sampling theory predicts that variability in contaminant concentrations for a given mass of soil will increase with increasing nominal particle size. Table 5-4 presents a summary of average grain-size distribution at the three study sites (see also Figures 4-1 through 4-4). Table 5-5 presents a summary of the average, <2mm size fraction of soil at the study sites. These samples were not processed prior to the collection of lab test portions, but laboratories routinely focus on the <2mm size fraction to collect test portions.

Both the intra- and inter-sample variability of contaminant concentrations is significantly higher in the coarser-grained, gravelly sands of Study Site B (median Total Variability = 6.8) and the fill area of Study Site C (median Total Variability = 33) in comparison to the clayey, fine sands of Study Site A (median Total Variability = 1.8). It is unclear that the difference in variability between the sites is controlled by grain size, however. The fill material at Site B contained a smaller amount of silt and clay than the fill material at Site C, but exhibited a distinctly lower (though still high) variability in contaminant concentrations. More significantly, the relative intra-sample variability of PCB concentrations reported for Study Site C is very similar between the fine-grained native soil and the coarser grained fill material. Table 5-6 compares the percent of silt and clay particles in the samples to the ratio of the maximum to minimum reported concentration of PCBs for the samples (again normalized with respect to the <2mm particle fraction that was tested). As depicted in Figure 5-13, there is no clear correlation between grain-size distribution and intra-sample variability.

The variability of PCB concentrations is likewise not clearly attributable to differences in particle-size distribution between fine-grained native soil and coarse-grained fill material at Study Site C (see Tables 4-20 and 4-21). Total variability in PCB concentrations is similar between the native, clayey silts in western area of the site (median Total Variability 94; range 7.1 to 895) and the gravelly sands of the eastern part of the site (median Total Variability 121; range 22 to 1,160). Variability was noticeably lower in the area of mixed native soil and fill material (median Total Variability 12; range 6.2 to 69), even though the normalized, <2mm grain-size distribution is similar to the fill soil (see Table 5-4). The cause of this difference is uncertain.

5.1.4 VARIABILITY AND CONTAMINANT CONCENTRATION

Sampling theory likewise predicts that small-scale variability in contaminant concentrations will increase with increasing mean concentration of the chemical. The mean concentration of PCBs in a sample does not appear to significantly control intra-sample variability, however (Figure 5-14). The ratio of maximum to minimum reported concentrations of PCBs in the samples as well as

the average RSD for samples is similar for the native soil and the fill material, even though the average concentrations vary dramatically (average 0.61 mg/kg and 1,135 mg/kg, respectively).

The high, intra-sample variability in lead and PCB concentrations at Study Sites B and C contrast sharply with the relatively low variability of arsenic at Study Site A (see Tables 4-3 and 5-1). Although the variability is relatively minor in comparison to the lead and PCB sites, it is still significant enough to warrant consideration with respect to implications for site investigations based solely on discrete samples. This is examined further in the Summary and Implications section of the report.

5.2 INTER-SAMPLE VARIABILITY

If distributional heterogeneity was consistent or “homogenous” within a large area of soil then the concentration of a contaminant within a set of co-located samples around a single grid point should be similar, provided that the samples were properly processed and subsampled for analysis. Other factors come into play, such as the mass of soil analyzed, but variability between co-located, processed samples could still be anticipated to be significantly lower than variability within single, unprocessed samples.

A significant reduction in the variability of contaminant concentrations is not apparent in the inter-sample variability data. The average magnitude of contaminant concentration variability for sets of co-located samples again clearly increases from Study Site A to Study Site B and again to Study Site C (see Table 5-1). Variability around any given grid point is likewise unpredictable (refer to Tables 4-6, 4-13 and 4-19).

A combination factors could be leading to this variability. It is possible, for example, that the mass of the subsample tested is simply inadequate to be representative of contaminant distribution within the sample, even after it has been processed. Ten gram subsamples were tested for arsenic and lead at Study Sites A and B, however, in comparison to one-gram masses of soil tested by the portable XRF. Replicate subsamples were not tested from processed soil samples. As noted in the next section, however, laboratory replicate data for MI samples collected at Study Site C were very consistent. Variability of contaminant concentrations over very small distances is more likely to once again be related to random, small-scale variations in contaminant distribution that are unrelated to larger-scale trends of interest. This issue will be explored in more detail in Part 2 of this study.

Regardless of the cause, the random variability of contaminant concentrations in what would traditionally be considered co-located samples, even when processed in the lab in accordance with incremental sampling methodologies, has significant implications for the use of discrete sample data in site investigations, risk assessment and design of remedial actions. These implications are briefly reviewed in Section 6 and will again be explored in more detail in Part 2 to this study.

5.3 TOTAL INTRA- AND INTER-SAMPLE VARIABILITY

A summary of the estimated, median, total discrete sample variability around grid points at each of the three study sites is noted in Table 5-1. The estimates are for illustration only. As noted above, additional testing of discrete samples would likely identify an even greater range of small-scale variability in contaminant concentrations around individual grid points.

Total variability is estimated based on adjustment of measured concentrations for each processed sample, assumed to represent the true mean for that sample, in terms of the RPD of minimum- and maximum-reported concentrations of the contaminant for the correlative, intra-sample variability data at the same grid point (Figures 4-1a-c; see Tables 4-3, 4-10 and 4-17). For example, the RPD between the minimum and maximum concentrations of arsenic in terms of the mean based on intra-sample data for Grid Point #1 at Study Site A is +/- 16% (see Table 4-3). The lowest concentration of arsenic reported for the set of co-located, processed discrete samples collected around the same grid point was 130 mg/kg (Sample WLP-1C; see Table 4-6). A high of 200 mg/kg was reported for the sample set (Sample WLP-1B). Adjusting the lowest concentration downward by 16% yields a predicted low concentration of a one-gram subsample collected within that sample of 109 mg/kg. Adjusting the highest concentration upward by the same percentage yields a predicted high, subsample concentration within that sample of 231 mg/kg. In total, this predicts a range of subsample-mass arsenic concentrations around the grid point of 109 mg/kg to 231 mg/kg (see Table 4-7). Note that this prediction applies to Method 6010B analysis as carried out for the processed samples.

Variability between co-located, discrete samples is similar in magnitude to variability measured within single samples at each of the study sites (see Table 5-1). Total variability in terms of the estimated range of minimum and maximum contaminant concentrations in discrete samples within 0.5m of a grid point progressively increases from Study Site A (arsenic, median estimated RPD 96%), to Study Site B (lead, median estimated RPD 650%) to Study Site C (PCBs, median estimated RPD 3,802%).

The mean, small-scale variability at Study Sites B and C are markedly higher and reflective of significantly greater variability of lead and PCB concentrations around some grid points. The mean RPD for small-scale, arsenic concentration variability at Study site A only slightly higher than the median, at 112% (maximum 308%). This reflects a relative consistency of small-scale variability around different grid points. The mean RPD for lead concentrations at Study Site B is distinctly higher than the median, at 879% and with a maximum estimated RPD 4,050%. The latter in particular reflects a stronger presence of “outlier” grid points characterized by markedly higher, small-scale variability. Both the median RPD of 3,082% and mean RPD of 19,550% for PCB concentrations in soil at Study Site C reflect the extreme, small-scale heterogeneity reported for discrete samples collected around individual grid points. The highest RPD for a grid point at Study Site C was estimated to be 115,916%.

As will be discussed in Part 2 of this study report, the relative increase in small-scale variability between the study sites is not unexpected based on the presumed mechanism of contaminant release and was indeed predicted prior to the collection of samples. Contamination at Study site A is associated with the release of arsenic-contaminated wastewater and/or water-based pesticides into fine-grained soils. This is the most opportune scenario to lead to a relatively low, small-scale distributional heterogeneity of a contaminant in soil. Contamination at Study Site B is believed to be related to incomplete mixing of lead-contaminated incinerator ash with native fill soil. As to be demonstrated in Part 2 of the report, this mixture is borne out in the variability of lead concentrations within samples and between in co-located samples, with minimum concentrations close to anticipated, natural background levels in soil and maximum concentrations clearly denoting the presence of incinerator ash. Total variability is greatest at Study Site C. This is interpreted to reflect a combination of isolated, small-scale release areas but also and perhaps more significantly the presence of PCB-infused “nuggets” of contaminated soil associated with beading of PCB-based oil released to the soil (refer to Section 5.1.2).

5.4 COMPARISON OF DISCRETE AND MULTI INCREMENT SAMPLE DATA SETS

Table 5-7 summarizes MIS triplicate data for each the study sites. The relative variability of this replicate data reflects variability recognized in the discrete samples. Variability was lowest in triplicate samples collected at Study Site A, arsenic site (relative standard deviation 6.5%). Variability of replicate data was somewhat higher at Study Site B, lead site (relative standard deviation 20%). Variability of replicate data was exceptionally high at Study Site C, with a relative standard deviation of 138%.

Table 5-8 summarizes the nature of the samples included in each data set for each study site and the mean concentration of the target contaminant estimated from the data. The mean for the discrete sample data set used to assess intra-sample variability reflects the collective average of the ten subsamples tested at each grid point. The mean for the inter-sample variability data set reflects the average of the five, processed samples tested at each grid point. The mean noted for the MI triplicate samples is simply the arithmetic average of those samples.

A comparison of mass and number of sample points represented by discrete versus incremental data sets and the mean contaminant concentration calculated for each data set is included in Table 5-8. Calculated mean concentrations are very similar for Study Sites A and B but differ dramatically for Study Site C. The similarity of means estimated for the first two study sites is in part a function of the relatively large number of discrete samples collected. Use of a fewer number of sample points would likely result in a greater divergence of the means. This will be tested in Part 2 of the study.

The true mean contaminant concentration at each study site could only be determined if the entire volume of soil was excavated and extracted and analyzed as a single sample. The most representative of the three data sets will be the data set that most closely approximates this test. Representativeness, by definition, requires control of sample collection bias as well as limits on

acceptable precision (Pitard 1993, 2009; Minnitt 2007). Control of bias includes such factors as appropriate location of sample/increment points, control of sample shape and mass, use of appropriate collection tools, and proper preparation and subsampling of the bulk sample for analysis.

Assuming for the purposes of illustration an equal control of bias between discrete and incremental samples, the relative representativeness of the sample sets can be in part evaluated in terms of the total mass of soil represented by the laboratory data (“sample support”) and the number of locations within the study site that contributed to this mass. In this case the intra-sample discrete data set is likely to be the *least* representative of the three. Soil was only collected from twenty-four locations from within each study site. Much worse, data for each grid point can only be said to represent ten grams of soil for Study Site A (arsenic) and Study Site B (lead) –one gram of soil for each of ten XRF analyses carried out on each sample. The calculated mean for each study site is thus based on testing of only 240g of soil within the study areas. The mass represented by the intra-sample data set for the PCB site is larger at 2,400g, since ten grams of soil were analyzed for each of the ten subsamples for a total mass of 100g represented by the data for each grid point. The reliability of a mean based on analysis of a single 1g or 10g mass of soil from each grid point, as would be the case in a normal discrete sample investigation, would be even lower. This will be reviewed in more detail in Part 2 of this study, including estimation of means and 95% UCLs for random groupings of sample points from each data set.

Data for the inter-sample variability sample set and the MI sample set reflect subsamples collected from processed soil samples. Assuming that lab processing and subsampling were carried out appropriately, the data can be said to represent the mass of the bulk samples submitted to the lab. In terms of total sample mass represented by the data the advantage clearly lies with data for the inter-sample variability sets of samples. Approximately one-kilogram of soil was processed, subsampled and analyzed at each grid point, for a sum total of 24 kg of soil per study area (see Table 5-8). This is a large amount of soil. This fact alone suggests an increased confidence in the estimated mean concentration of contaminants within the study areas for this set of data. A drawback is that the soil was, for all practical purposes, collected from only 24 locations within each study area.

The total mass of soil represented by the triplicate MI samples is approximately 4.5kgs. This is higher than the mass of soil represented by the unprocessed, discrete intra-sample data sets but significantly lower than the mass represented by the processed, discrete inter-sample data sets. A significant advantage of the MI data set is that the data represent masses of soil collected from 162 (Study Sites A and B) to 180 (Study Site C), independent locations within the study sites. The mean concentrations of arsenic and lead calculated for Study Sites A and B based on the processed discrete data and the MI triplicates are essentially identical. This suggests that the precision of both approaches is comparable. The former required analyses of 120 samples (five per grid point), however, in comparison to analysis of only three samples for the MI data set.

Replicate MI samples also provide insight into the reproducibility of the data. The reproducibility of the discrete sample data cannot be proven in the absence of additional, independent sets of sample data.

Determining which of the two data sets is more representative of the mean concentration of PCBs at Study Site C is more problematic. The mean calculated as the average of the processed, discrete samples is higher (220 mg/kg) but again this is not an indicator of representativeness. The high variability of data for processed samples around individual grid points (average max:min ratio 11) implies significant distributional heterogeneity and calls into question the reliability of the mean concentration estimated for each point. A more detailed review of this data set and potential error in estimate of the mean will be included in Part 2 of this study.

An important advantage of the MI sample data is that representativeness in terms of field precision can be tested through the collection and comparison of replicates. The MI replicate RSD of 138% for Study Site C quickly calls into question the representativeness of the data. Retesting of replicates samples for Study Site C MI samples yielded identical results, suggesting the data are representative of the samples and that the variability between replicates is not an artifact of lab error. The high RSD immediately questions the representativeness of any one MI sample. A 95% UCL value of 346 mg/kg was calculated for the PCB MI data, well above the arithmetic mean of 104 mg/kg, even though the 60 increments were included in each sample (total 180 points; see Table 5-7).

Review of the MI PCB data implies two possible sources of error: 1) The collection of soil increments from too few locations within the study area and/or 2) The presence of one or more significantly more contaminated subareas within the study area. The latter is already suspected based on the site history and previous sampling as well as discrete sample data collected as part of the study. In practice, the areas of native soil and fill material would have been investigated as separate DUs, with the intervening area possibly designated as a third DU.

6 SUMMARY AND IMPLICATIONS

The study was initiated to review three simple questions that are often in the back of the field sampler's mind: 1) How different might the result be if the lab selected and tested another, random test portion of soil from the sample submitted?, 2) How different might the result be if the sample collection point was moved over a few inches or a few feet?, and 3) How many samples need to be collected to determine a representative mean contaminant concentration? Based on the data collected the answer to the first two questions is “very different”, and answer to the third question is more than 24 discrete samples (or increments) per DU, but could be considerably higher depending on site characteristics, DU selection/placement, and chemical type. In addition, the data from this study highlight the importance of collecting and evaluating field replicate data as well as lab sub-sampling replicate data to determine the representativeness of any field sampling investigation.

Discrete soil samples are not routinely processed prior to analysis. The data provided by the laboratory can therefore be assumed to represent no more than the mass of soil actually tested, typically one to thirty grams depending on the lab method and the target analyte. Based on the data collected as part of this study the concentration of a contaminant in lab test portion-size masses of soil can be expected to vary by a factor of two to over one-hundred within just one to two feet of a grid point. This variability is random and cannot be assumed to be representative of larger-scale trends of contaminant distribution across a site.

The implications are significant. For example, the presence of small-scale, random variability of contaminant concentrations in soil introduces significant uncertainty in the reliability of **isoconcentration maps** based on discrete sample data. The ability of isoconcentration contours to predict the concentration of a chemical for any given area of a site is completely controlled by the accuracy of individual data points to reflect large-scale trends. Large-scale patterns implied by the data may indeed be real, but individual isoconcentration contours cannot be assumed to be accurate. Boundary zones between “clean” and “contaminated” areas should be anticipated to be marked by seemingly smaller-scale and randomly located “**hot spots**” and “**cold spots.**” These spots simply reflect the magnitude of small-scale variability within the overall area. They are unlikely to be “real” in the sense that they could be mapped or replicated. Attempts to remove isolated “hot spots” based on discrete sample data would be futile and cannot be assumed to have reduced the overall risk posed by contamination in the area as a whole. Misinterpretation of discrete sample “cold spots” within an otherwise contaminated area can lead to premature termination of a site investigation.

The potential for error in decision making is clearly evident in discrete sample data for lead-contaminated soil at Study Site B. The range of lead concentrations reported for XRF tests at 18 of the 24 grid points coincidentally falls both above and below the HDOH residential soil screening level of 200 mg/kg (Figure 6-1, see also Table 4-9; HDOH 2011b). Random selection of a lead concentration for each grid point could declare the majority of the site “clean” or

“contaminated,” depending on which data were selected for each grid point. Failure to understand this characteristic of the site could lead to **multiple remobilizations** to collect additional discrete sample data, **false negatives** and an **underestimation of the extent of contamination** in areas where variability overlaps the target screening level, **failed confirmation samples** after initial removal of contaminated soil, and the need for **repeated over excavations**. The study site in fact lies within a much larger area of lead- and incinerator ash-contaminated soil that covers several acres of land, identified as part of a DU-MIS investigation (report pending).

The significance of false negatives increases as the random, small-scale variability of contaminant concentrations within soil increases. This is especially evident for investigations of **PCB-contaminated soil**. These investigations are plagued by the problems noted above. As documented in this study and observed at numerous other sites, the range of PCB concentrations reported for sets of individual samples can be extremely large, due to significant, small-scale heterogeneity. This can lead to highly skewed data, with extreme and seemingly non-representative “outliers” scattered across a site. As will be discussed in more detail in Part 2, however, the discrete data are “real” in the sense that they reflect small-scale variability of PCB concentrations within the area. The data also collectively reflect the mean concentration of PCBs within the area. Misunderstanding of the cause of this variability leads to one of the most striking types of decision error in the use of discrete data – the **exclusion of “outlier” data in risk assessments** in order to fit the data to a geostatistical model that was not designed to deal with this type of variability (e.g., USEPA ProUCL guidance; USEPA 2013).

Experience at a similar PCB-contaminated site in Hawai‘i was used as a case study of the unreliability of discrete sampling methods in a recent guidance document on incremental sampling methodologies (Molokai Electric; ITRC 2012). In that study, DU-MIS investigation data indicate that earlier, discrete sample data underestimate the extent of PCB contamination at the site by over 200%. The collection of discrete soil samples at PCB-contaminated sites is required in some sections of 1980s-era regulations and guidance prepared under the **Toxic Substances Control Act (TSCA)**, however. In several cases this has led to a requirement by the USEPA to cease DU-MIS investigations at PCB-contaminated sites and, ironically, revert to the collection of yet more discrete samples for decision making purposes or to collect two separate sets of both MIS and discrete samples. The results of this study are being used to support development of an updated, technical and regulatory pathway for the standalone use of Decision Unit and incremental sampling methodologies to characterize, assess and dispose of PCB-contaminated soil for cases that fall under TSCA oversight.

The results of the study also call the use of relatively small (e.g., <20-30) sets of discrete soil samples in **risk assessments** into questionable. The representativeness of a data set in terms of *bias* is not routinely controlled in discrete sample collection or processing at the laboratory (e.g., ensuring proper sample size, shape and mass; processing of samples to obtain a representativeness subsample for testing, etc.). Most critically, the *field precision* of a data set

cannot be quantitatively tested. Statistical analysis of a single data set only evaluates the precision of the *test method* applied (e.g., Student's t test or Chebyshev test) in terms of the data set provided. Precision in terms of the representativeness of the data set itself cannot be quantitatively evaluated. This is evaluated in DU-MIS investigations through the collection of replicate samples. Risk assessors are instead forced to assume that the discrete sample data set they are provided with is indeed representative of the area under investigation.

The study suggests that past USEPA guidance recommendations for the use of at least 20 to 30 discrete samples to represent an area and estimate the mean contaminant concentration appears to be adequate for sites with relatively low heterogeneity (e.g., Study Site A). A significantly larger number of samples (or increments) is required to represent moderate or high heterogeneous sites (e.g., Study Site C). Exclusion of "outlier" sample data to force a data set to fit a geostatistical model and artificially increase precision is not technically defensible.

The issues described above as well as other factors that can lead to decision errors based on the use of discrete soil sample data in environmental investigations is explored in more detail in Part 2 of this study.

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Table 4-1. Study Site A soil grain-size distribution.

Sample ID	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
WLP-1A	0.0%	0.2%	23%	57%	4.7%	15%
WLP-2A	0.0%	0.7%	20%	59%	4.8%	16%
WLP-3A	0.0%	0.0%	14%	63%	4.9%	18%
WLP-4A	0.0%	0.6%	16%	59%	4.7%	20%
WLP-5A	0.0%	1.4%	18%	57%	6.5%	18%
WLP-6A	0.0%	2.5%	16%	60%	4.5%	17%
WLP-7A	0.0%	0.3%	16%	48%	7.9%	28%
WLP-8A	0.0%	0.4%	14%	56%	4.8%	25%
WLP-9A	2.0%	3.1%	41%	37%	9.5%	8%
WLP-10A	0.0%	0.3%	11%	69%	4.7%	14%
WLP-11A	0.0%	0.1%	12%	72%	3.1%	14%
WLP-12A	0.1%	0.2%	16%	71%	3.1%	9%
WLP-13A	0.0%	0.8%	13%	68%	3.1%	15%
WLP-14A	0.0%	0.2%	11%	72%	3.1%	14%
WLP-15A	0.1%	0.3%	10%	73%	1.5%	15%
WLP-16A	0.0%	0.4%	16%	70%	1.5%	12%
WLP-17A	0.1%	0.8%	11%	69%	1.6%	17%
WLP-18A	0.3%	0.3%	13%	71%	3.2%	12%
WLP-19A	0.0%	0.2%	15%	65%	3.2%	16%
WLP-20A	2.0%	0.6%	25%	56%	1.5%	15%
WLP-21A	0.4%	0.8%	19%	62%	3.2%	15%
WLP-22A	0.2%	1.3%	20%	57%	3.2%	18%
WLP-23A	0.1%	0.4%	10%	70%	3.2%	17%
WLP-24A	0.4%	0.3%	9%	72%	4.7%	13%
Average:	0.2%	0.7%	16%	63%	4.0%	16%

Table 4-2. Study Site A arsenic intra-sample variability data (XRF data).

Sample ID	Arsenic (mg/kg)														
WLP-1A	255	WLP-2A	144	WLP-3A	541	WLP-4A	637	WLP-5A	544	WLP-6A	363	WLP-7A	183	WLP-8A	233
WLP-1A	250	WLP-2A	172	WLP-3A	500	WLP-4A	719	WLP-5A	538	WLP-6A	351	WLP-7A	176	WLP-8A	270
WLP-1A	274	WLP-2A	165	WLP-3A	454	WLP-4A	554	WLP-5A	677	WLP-6A	378	WLP-7A	185	WLP-8A	212
WLP-1A	259	WLP-2A	161	WLP-3A	587	WLP-4A	733	WLP-5A	559	WLP-6A	340	WLP-7A	165	WLP-8A	237
WLP-1A	276	WLP-2A	165	WLP-3A	633	WLP-4A	615	WLP-5A	573	WLP-6A	353	WLP-7A	172	WLP-8A	218
WLP-1A	331	WLP-2A	196	WLP-3A	691	WLP-4A	1,412	WLP-5A	674	WLP-6A	416	WLP-7A	187	WLP-8A	264
WLP-1A	346	WLP-2A	172	WLP-3A	642	WLP-4A	876	WLP-5A	701	WLP-6A	423	WLP-7A	217	WLP-8A	282
WLP-1A	342	WLP-2A	199	WLP-3A	656	WLP-4A	884	WLP-5A	695	WLP-6A	394	WLP-7A	189	WLP-8A	295
WLP-1A	335	WLP-2A	169	WLP-3A	601	WLP-4A	765	WLP-5A	873	WLP-6A	374	WLP-7A	206	WLP-8A	260
WLP-1A	322	WLP-2A	204	WLP-3A	615	WLP-4A	815	WLP-5A	740	WLP-6A	394	WLP-7A	193	WLP-8A	299
WLP-9A	565	WLP-10A	373	WLP-11A	386	WLP-12A	460	WLP-13A	389	WLP-14A	470	WLP-15A	305	WLP-16A	390
WLP-9A	528	WLP-10A	442	WLP-11A	351	WLP-12A	413	WLP-13A	324	WLP-14A	421	WLP-15A	373	WLP-16A	392
WLP-9A	480	WLP-10A	418	WLP-11A	285	WLP-12A	462	WLP-13A	324	WLP-14A	468	WLP-15A	288	WLP-16A	390
WLP-9A	499	WLP-10A	470	WLP-11A	368	WLP-12A	501	WLP-13A	382	WLP-14A	474	WLP-15A	291	WLP-16A	377
WLP-9A	478	WLP-10A	454	WLP-11A	312	WLP-12A	460	WLP-13A	322	WLP-14A	406	WLP-15A	252	WLP-16A	572
WLP-9A	497	WLP-10A	533	WLP-11A	381	WLP-12A	546	WLP-13A	389	WLP-14A	555	WLP-15A	378	WLP-16A	721
WLP-9A	563	WLP-10A	523	WLP-11A	381	WLP-12A	552	WLP-13A	449	WLP-14A	492	WLP-15A	330	WLP-16A	562
WLP-9A	549	WLP-10A	573	WLP-11A	392	WLP-12A	513	WLP-13A	435	WLP-14A	553	WLP-15A	387	WLP-16A	546
WLP-9A	591	WLP-10A	583	WLP-11A	333	WLP-12A	567	WLP-13A	429	WLP-14A	578	WLP-15A	348	WLP-16A	546
WLP-9A	553	WLP-10A	533	WLP-11A	396	WLP-12A	511	WLP-13A	437	WLP-14A	547	WLP-15A	330	WLP-16A	482
WLP-17A	168	WLP-18A	158	WLP-19A	183	WLP-20A	208	WLP-21A	296	WLP-22A	276	WLP-23A	291	WLP-24A	180
WLP-17A	190	WLP-18A	175	WLP-19A	222	WLP-20A	202	WLP-21A	314	WLP-22A	259	WLP-23A	241	WLP-24A	144
WLP-17A	174	WLP-18A	213	WLP-19A	181	WLP-20A	200	WLP-21A	316	WLP-22A	236	WLP-23A	257	WLP-24A	177
WLP-17A	178	WLP-18A	188	WLP-19A	183	WLP-20A	208	WLP-21A	384	WLP-22A	241	WLP-23A	281	WLP-24A	210
WLP-17A	176	WLP-18A	229	WLP-19A	187	WLP-20A	218	WLP-21A	371	WLP-22A	249	WLP-23A	265	WLP-24A	195
WLP-17A	186	WLP-18A	239	WLP-19A	185	WLP-20A	186	WLP-21A	335	WLP-22A	291	WLP-23A	306	WLP-24A	155
WLP-17A	201	WLP-18A	242	WLP-19A	211	WLP-20A	210	WLP-21A	398	WLP-22A	299	WLP-23A	314	WLP-24A	229
WLP-17A	205	WLP-18A	266	WLP-19A	202	WLP-20A	204	WLP-21A	296	WLP-22A	317	WLP-23A	291	WLP-24A	208
WLP-17A	209	WLP-18A	258	WLP-19A	207	WLP-20A	204	WLP-21A	396	WLP-22A	284	WLP-23A	298	WLP-24A	221
WLP-17A	194	WLP-18A	258	WLP-19A	191	WLP-20A	189	WLP-21A	371	WLP-22A	319	WLP-23A	293	WLP-24A	239

Table 4-3. Study Site A summary of arsenic intra-sample variability (XRF data).

Sample ID	Min (mg/kg)	Mean (mg/kg)	Max (mg/kg)	Max:Min Ratio	² RPD (Max:Min)	³ RPD (Min:Mean)	³ RPD (Max:Mean)	SD	RSD
WLP-1A	250	299	346	1.4	38%	-16%	16%	39	13%
WLP-2A	144	175	204	1.4	41%	-17%	17%	19	11%
WLP-3A	454	592	691	1.5	52%	-23%	17%	74	12%
WLP-4A	554	801	1,412	2.5	155%	-31%	76%	241	30%
WLP-5A	538	657	873	1.6	62%	-18%	33%	106	16%
WLP-6A	340	379	423	1.2	25%	-10%	12%	28	7%
WLP-7A	165	187	217	1.3	32%	-12%	16%	16	8%
WLP-8A	212	257	299	1.4	41%	-17%	16%	31	12%
WLP-9A	478	530	591	1.2	24%	-10%	11%	40	7%
WLP-10A	373	490	583	1.6	56%	-24%	19%	69	14%
WLP-11A	285	359	396	1.4	39%	-20%	10%	37	10%
WLP-12A	413	499	567	1.4	37%	-17%	14%	49	10%
WLP-13A	322	388	449	1.4	39%	-17%	16%	50	13%
WLP-14A	406	496	578	1.4	43%	-18%	16%	59	12%
WLP-15A	252	328	387	1.5	54%	-23%	18%	44	14%
WLP-16A	377	498	721	1.9	91%	-24%	45%	112	23%
WLP-17A	168	188	209	1.2	25%	-11%	11%	14	8%
WLP-18A	158	223	266	1.7	68%	-29%	20%	38	17%
WLP-19A	181	195	222	1.2	22%	-7%	14%	14	7%
WLP-20A	186	203	218	1.2	17%	-8%	8%	10	5%
WLP-21A	296	348	398	1.3	34%	-15%	14%	41	12%
WLP-22A	236	277	319	1.4	35%	-15%	15%	30	11%
WLP-23A	241	284	314	1.3	31%	-15%	11%	23	8%
WLP-24A	144	196	239	1.7	67%	-27%	22%	32	16%
Average:	299	369	455	1.5	47%	-18%	19%	-	12%

1. See Table 4-2. Relative Percent Difference (RPD) as noted, Standard Deviation (SD) and Relative Standard Deviation (RSD).

2. Percent difference maximum-reported concentration of arsenic in discrete sample subsamples relative to the minimum-reported concentration [RPD = ((Max-Min)/Min x 100%].

3. Percent difference minimum-reported and maximum-reported concentrations of arsenic in discrete sample subsamples relative to the mean concentration [e.g., RPD = ((Max-Mean)/Mean x 100%].

Table 4-4. Study Site A arsenic inter-sample variability data (Method 6010B data).

Sample ID	Arsenic (mg/kg)										
WLP-1A	200	WLP-2A	140	WLP-3A	360	WLP-4A	410	WLP-5A	350	WLP-6A	300
WLP-1B	180	WLP-2B	120	WLP-3B	290	WLP-4B	380	WLP-5B	340	WLP-6B	290
WLP-1C	130	WLP-2C	230	WLP-3C	350	WLP-4C	410	WLP-5C	330	WLP-6C	290
WLP-1D	170	WLP-2D	260	WLP-3D	280	WLP-4D	330	WLP-5D	300	WLP-6D	290
WLP-1E	190	WLP-2E	120	WLP-3E	300	WLP-4E	430	WLP-5E	310	WLP-6E	290
WLP-7A	110	WLP-8A	180	WLP-9A	300	WLP-10A	330	WLP-11A	300	WLP-12A	350
WLP-7B	84	WLP-8B	190	WLP-9B	350	WLP-10B	340	WLP-11B	330	WLP-12B	340
WLP-7C	130	WLP-8C	230	WLP-9C	200	WLP-10C	300	WLP-11C	460	WLP-12C	330
WLP-7D	150	WLP-8D	270	WLP-9D	290	WLP-10D	270	WLP-11D	300	WLP-12D	370
WLP-7E	94	WLP-8E	230	WLP-9E	180	WLP-10E	330	WLP-11E	330	WLP-12E	380
WLP-13A	310	WLP-14A	380	WLP-15A	250	WLP-16A	300	WLP-17A	150	WLP-18A	180
WLP-13B	330	WLP-14B	400	WLP-15B	240	WLP-16B	150	WLP-17B	150	WLP-18B	180
WLP-13C	310	WLP-14C	270	WLP-15C	230	WLP-16C	220	WLP-17C	120	WLP-18C	160
WLP-13D	290	WLP-14D	310	WLP-15D	260	WLP-16D	320	WLP-17D	100	WLP-18D	180
WLP-13E	270	WLP-14E	350	WLP-15E	290	WLP-16E	210	WLP-17E	190	WLP-18E	170
WLP-19A	110	WLP-20A	130	WLP-21A	260	WLP-22A	150	WLP-23A	200	WLP-24A	160
WLP-19B	130	WLP-20B	150	WLP-21B	200	WLP-22B	180	WLP-23B	230	WLP-24B	190
WLP-19C	120	WLP-20C	180	WLP-21C	260	WLP-22C	140	WLP-23C	200	WLP-24C	130
WLP-19D	110	WLP-20D	140	WLP-21D	270	WLP-22D	140	WLP-23D	230	WLP-24D	170
WLP-19E	110	WLP-20E	150	WLP-21E	240	WLP-22E	140	WLP-23E	200	WLP-24E	140

Table 4-5. Comparison of XRF and Method 6010B (3050B) data for Study Site A.

Sample ID	Arsenic			Copper			Iron			Zinc		
	XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference	XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference	XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference	XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference
WLP-1A	299	200	33%	69	27	61%	125,394	44,000	65%	211	130	39%
WLP-2A	175	140	20%	53	22	59%	104,687	49,000	53%	129	89	31%
WLP-3A	592	360	39%	87	32	63%	134,493	48,000	64%	249	140	44%
WLP-4A	801	410	49%	95	32	66%	166,650	44,000	74%	241	110	54%
WLP-5A	657	350	47%	98	32	67%	159,323	44,000	72%	267	110	59%
WLP-6A	379	300	21%	61	31	49%	109,194	44,000	60%	175	120	31%
WLP-7A	187	110	41%	70	34	52%	134,371	47,000	65%	246	160	35%
WLP-8A	257	180	30%	52	23	56%	123,985	44,000	65%	148	92	38%
WLP-9A	530	300	43%	81	34	58%	113,911	34,000	70%	177	93	48%
WLP-10A	490	330	33%	70	36	49%	124,602	45,000	64%	207	140	32%
WLP-11A	359	300	16%	60	31	48%	102,145	43,000	58%	162	120	26%
WLP-12A	499	350	30%	63	32	49%	117,880	43,000	64%	183	120	35%
WLP-13A	388	310	20%	75	36	52%	119,485	44,000	63%	240	150	38%
WLP-14A	496	380	23%	73	36	51%	126,061	46,000	64%	245	160	35%
WLP-15A	328	250	24%	79	34	57%	138,649	47,000	66%	241	130	46%
WLP-16A	498	300	40%	84	31	63%	153,723	45,000	71%	228	110	52%
WLP-17A	188	150	20%	64	31	51%	121,248	46,000	62%	208	140	33%
WLP-18A	223	180	19%	72	33	54%	118,340	43,000	64%	217	130	40%
WLP-19A	194	110	43%	87	44	50%	127,370	43,000	66%	299	190	36%
WLP-20A	203	130	36%	87	42	52%	116,951	40,000	66%	261	180	31%
WLP-21A	348	260	25%	83	46	45%	106,496	43,000	60%	253	190	25%
WLP-22A	277	150	46%	104	47	55%	137,115	42,000	69%	342	200	41%
WLP-23A	284	200	29%	67	31	54%	119,570	42,000	65%	226	140	38%
WLP-24A	196	160	18%	55	31	43%	104,287	44,000	58%	180	140	22%
Average:	369	246	31%	75	34	54%	125,247	43,917	64%	222	137	38%

Table 4-6. Study Site A summary of arsenic inter-sample variability¹ (Method 6010B data).

Grid Point	Min (mg/kg)	Mean (mg/kg)	Max (mg/kg)	Max:Min Ratio	²RPD (Max:Min)	SD	RSD
WLP-1	130	174	200	1.5	54%	27	16%
WLP-2	120	174	260	2.2	117%	66	38%
WLP-3	280	316	360	1.3	29%	36	12%
WLP-4	330	392	430	1.3	30%	39	10%
WLP-5	300	326	350	1.2	17%	21	6.4%
WLP-6	290	292	300	1.0	3%	4	1.5%
WLP-7	84	114	150	1.8	79%	27	24%
WLP-8	180	220	270	1.5	50%	36	16%
WLP-9	180	264	350	1.9	94%	72	27%
WLP-10	270	314	340	1.3	26%	29	9.2%
WLP-11	300	344	460	1.5	53%	67	19%
WLP-12	330	354	380	1.2	15%	21	5.9%
WLP-13	270	302	330	1.2	22%	23	7.6%
WLP-14	270	342	400	1.5	48%	53	15%
WLP-15	230	254	290	1.3	26%	23	9.1%
WLP-16	150	240	320	2.1	113%	70	29%
WLP-17	100	142	190	1.9	90%	34	24%
WLP-18	160	174	180	1.1	13%	9	5.1%
WLP-19	110	116	130	1.2	18%	9	7.7%
WLP-20	130	150	180	1.4	38%	19	12%
WLP-21	200	246	270	1.4	35%	28	11%
WLP-22	140	150	180	1.3	29%	17	12%
WLP-23	200	212	230	1.2	15%	16	7.8%
WLP-24	130	158	190	1.5	46%	24	15%
Average:	204	240	281	1.4	44%	-	14%

1. See Table 4-4. Relative Percent Difference (RPD) between maximum- and minimum-reported concentration, Standard Deviation (SD) and Relative Standard Deviation (RSD).

2. Percent difference maximum-reported concentration of arsenic in co-located discrete samples around individual grid points relative to the minimum-reported concentration [RPD = ((Max-Min)/Min x 100%].

Table 4-7. Study Site A summary of combined arsenic intra- and inter-sample variability.

Grid Point	¹ Average Arsenic Concentration		Max:Min Ratio		² Estimated Total Discrete Samples Range			
	Intra-Sample Data (mg/kg)	Inter-Sample Data (mg/kg)	Intra-Sample Variability	Inter-Sample Variability	Adjusted Min (mg/kg)	Adjusted Max (mg/kg)	Max:Min Ratio	³ RPD (Max:Min)
WLP-1	299	174	1.4	1.5	109	231	2.1	113%
WLP-2	175	174	1.4	2.2	99	303	3.1	206%
WLP-3	592	316	1.5	1.3	215	420	2.0	95%
WLP-4	801	392	2.5	1.3	228	758	3.3	232%
WLP-5	657	326	1.6	1.2	245	465	1.9	90%
WLP-6	379	292	1.2	1.0	260	335	1.3	29%
WLP-7	187	114	1.3	1.8	74	174	2.3	135%
WLP-8	257	220	1.4	1.5	149	314	2.1	111%
WLP-9	530	264	1.2	1.9	162	390	2.4	140%
WLP-10	490	314	1.6	1.3	206	405	2.0	97%
WLP-11	359	344	1.4	1.5	239	508	2.1	113%
WLP-12	499	354	1.4	1.2	273	432	1.6	58%
WLP-13	388	302	1.4	1.2	224	382	1.7	70%
WLP-14	496	342	1.4	1.5	221	466	2.1	111%
WLP-15	328	254	1.5	1.3	177	342	1.9	94%
WLP-16	498	240	1.9	2.1	114	463	4.1	308%
WLP-17	188	142	1.2	1.9	89	212	2.4	137%
WLP-18	223	174	1.7	1.1	114	215	1.9	89%
WLP-19	195	116	1.2	1.2	102	148	1.4	45%
WLP-20	203	150	1.2	1.4	119	194	1.6	62%
WLP-21	348	246	1.3	1.4	170	309	1.8	81%
WLP-22	277	150	1.4	1.3	119	207	1.7	74%
WLP-23	284	212	1.3	1.2	170	255	1.5	50%
WLP-24	196	158	1.7	1.5	95	232	2.4	144%
Minimum:	175	114	1.2	1.0	74	148	1.3	29%
Maximum:	801	392	2.5	2.2	273	758	4.1	308%
Mean:	369	240	1.5	1.4	166	340	2.1	112%
Median:	338	243	1.4	1.3	166	325	2.0	96%

1. Intra-sample data based on XRF analysis; inter-sample data based on ICP Method 6010B. XRF data will be higher for arsenic.
2. Estimated total range of minimum and maximum concentration of arsenic for hypothetical, discrete soil samples collected within 0.5m of a grid point, based on adjustment of processed sample data (see Table 4-6) downwards and upwards with respect to RPDs measured for intra-sample data set from same grid point (see Table 4-3). Reflects estimates for lab analyzed data; XRF concentrations would be higher (see Table 4-5). For illustration purposes only; accuracy of estimates is uncertain.
3. Relative percent difference between estimated minimum and maximum concentrations of arsenic in discrete samples within a 0.5m radius of a grid point [RPD = ((Max-Min)/Min x 100%).

Table 4-8. Study Site B soil grain-size distribution.

Sample ID	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
WI-1A	6.1%	4.4%	24%	56%	8.0%	1.7%
WI-2A	7.3%	19%	38%	31%	3.3%	2.1%
WI-3A	5.5%	10%	36%	44%	0.6%	3.3%
WI-4A	32%	15%	18%	24%	9.8%	1.7%
WI-5A	20%	10%	30%	35%	3.5%	1.3%
WI-6A	10%	11%	32%	40%	4.7%	2.4%
WI-7A	14%	10%	24%	41%	8.7%	1.4%
WI-8A	12%	13%	30%	36%	7.2%	1.4%
WI-9A	8.1%	11%	37%	34%	6.5%	2.9%
WI-10A	6.5%	11%	35%	39%	5.7%	3.1%
WI-11A	3.7%	7.4%	30%	46%	10%	2.5%
WI-12A	25%	16%	22%	29%	6.9%	1.5%
WI-13A	13%	10%	30%	38%	6.2%	2.7%
WI-14A	15%	20%	42%	21%	0.8%	2.5%
WI-15A	8.9%	15%	42%	29%	2.0%	4.2%
WI-16A	10%	16%	33%	32%	4.4%	5.1%
WI-17A	19%	13%	38%	25%	0.6%	4.8%
WI-18A	14%	23%	43%	17%	0.0%	6.4%
WI-19A	18%	13%	29%	31%	4.4%	4.8%
WI-20A	23%	9%	26%	32%	7.4%	2.8%
WI-21A	2.1%	5.0%	33%	33%	23%	4.0%
WI-22A	37%	5.0%	15%	22%	19%	2.0%
WI-23A	6.7%	4.2%	27%	32%	26%	3.5%
WI-24A	26%	6.1%	20%	24%	21%	3.1%
Average:	14%	11%	31%	33%	7.9%	3.0%

1. Sum of percentages reported by laboratory may not equal 100% due to lab method used.

Table 4-9. Study Site B lead intra-sample variability data (XRF data).

Sample ID	Lead (mg/kg)														
WI-1A	232	WI-2A	276	WI-3A	366	WI-4A	585	WI-5A	67	WI-6A	55	WI-7A	327	WI-8A	361
WI-1A	222	WI-2A	270	WI-3A	349	WI-4A	462	WI-5A	56	WI-6A	41	WI-7A	295	WI-8A	396
WI-1A	219	WI-2A	89	WI-3A	261	WI-4A	283	WI-5A	139	WI-6A	212	WI-7A	191	WI-8A	259
WI-1A	244	WI-2A	19	WI-3A	235	WI-4A	334	WI-5A	188	WI-6A	185	WI-7A	337	WI-8A	338
WI-1A	359	WI-2A	40	WI-3A	317	WI-4A	643	WI-5A	152	WI-6A	327	WI-7A	166	WI-8A	353
WI-1A	231	WI-2A	67	WI-3A	286	WI-4A	812	WI-5A	168	WI-6A	372	WI-7A	270	WI-8A	261
WI-1A	355	WI-2A	87	WI-3A	252	WI-4A	1,014	WI-5A	140	WI-6A	167	WI-7A	222	WI-8A	259
WI-1A	176	WI-2A	101	WI-3A	320	WI-4A	799	WI-5A	60	WI-6A	253	WI-7A	216	WI-8A	170
WI-1A	269	WI-2A	32	WI-3A	98	WI-4A	556	WI-5A	173	WI-6A	236	WI-7A	311	WI-8A	85
WI-1A	224	WI-2A	64	WI-3A	212	WI-4A	703	WI-5A	63	WI-6A	84	WI-7A	214	WI-8A	193
WI-9A	74	WI-10A	198	WI-11A	284	WI-12A	444	WI-13A	285	WI-14A	234	WI-15A	203	WI-16A	457
WI-9A	94	WI-10A	131	WI-11A	221	WI-12A	343	WI-13A	249	WI-14A	156	WI-15A	195	WI-16A	308
WI-9A	176	WI-10A	88	WI-11A	198	WI-12A	263	WI-13A	275	WI-14A	171	WI-15A	367	WI-16A	238
WI-9A	65	WI-10A	147	WI-11A	168	WI-12A	525	WI-13A	197	WI-14A	195	WI-15A	208	WI-16A	269
WI-9A	101	WI-10A	265	WI-11A	234	WI-12A	659	WI-13A	223	WI-14A	221	WI-15A	230	WI-16A	289
WI-9A	164	WI-10A	223	WI-11A	237	WI-12A	345	WI-13A	188	WI-14A	207	WI-15A	276	WI-16A	292
WI-9A	113	WI-10A	86	WI-11A	253	WI-12A	307	WI-13A	173	WI-14A	69	WI-15A	145	WI-16A	286
WI-9A	38	WI-10A	55	WI-11A	173	WI-12A	501	WI-13A	111	WI-14A	85	WI-15A	209	WI-16A	412
WI-9A	126	WI-10A	85	WI-11A	253	WI-12A	250	WI-13A	135	WI-14A	225	WI-15A	168	WI-16A	305
WI-9A	114	WI-10A	62	WI-11A	150	WI-12A	378	WI-13A	129	WI-14A	118	WI-15A	131	WI-16A	324
WI-17A	243	WI-18A	344	WI-19A	686	WI-20A	654	WI-21A	168	WI-22A	200	WI-23A	98	WI-24A	280
WI-17A	171	WI-18A	308	WI-19A	558	WI-20A	523	WI-21A	133	WI-22A	233	WI-23A	200	WI-24A	241
WI-17A	193	WI-18A	123	WI-19A	177	WI-20A	245	WI-21A	209	WI-22A	324	WI-23A	155	WI-24A	194
WI-17A	185	WI-18A	209	WI-19A	584	WI-20A	350	WI-21A	167	WI-22A	188	WI-23A	103	WI-24A	274
WI-17A	255	WI-18A	327	WI-19A	322	WI-20A	734	WI-21A	238	WI-22A	352	WI-23A	121	WI-24A	298
WI-17A	362	WI-18A	291	WI-19A	539	WI-20A	681	WI-21A	321	WI-22A	239	WI-23A	71	WI-24A	117
WI-17A	305	WI-18A	504	WI-19A	598	WI-20A	596	WI-21A	125	WI-22A	259	WI-23A	86	WI-24A	131
WI-17A	677	WI-18A	364	WI-19A	431	WI-20A	723	WI-21A	213	WI-22A	298	WI-23A	50	WI-24A	249
WI-17A	299	WI-18A	431	WI-19A	578	WI-20A	642	WI-21A	245	WI-22A	283	WI-23A	30	WI-24A	188
WI-17A	422	WI-18A	240	WI-19A	387	WI-20A	679	WI-21A	249	WI-22A	1,396	WI-23A	29	WI-24A	119

Table 4-10. Study Site B summary of lead intra-sample variability (XRF data).

Sample ID	Min (mg/kg)	Mean (mg/kg)	Max (mg/kg)	Max:Min Ratio	² RPD (Max:Min)	³ RPD (Min:Mean)	³ RPD (Max:Mean)	SD	RSD
WI-1A	176	253	359	2.0	104%	-30%	42%	59	23%
WI-2A	19	105	276	14.5	1353%	-82%	164%	93	89%
WI-3A	98	270	366	3.7	273%	-64%	36%	78	29%
WI-4A	283	619	1,014	3.6	258%	-54%	64%	225	36%
WI-5A	56	121	188	3.4	236%	-54%	56%	53	44%
WI-6A	41	193	372	9.1	807%	-79%	93%	111	57%
WI-7A	166	255	337	2.0	103%	-35%	32%	61	24%
WI-8A	85	268	396	4.7	366%	-68%	48%	98	37%
WI-9A	38	107	176	4.6	363%	-64%	65%	43	40%
WI-10A	55	134	265	4.8	382%	-59%	98%	73	54%
WI-11A	150	217	284	1.9	89%	-31%	31%	43	20%
WI-12A	250	402	659	2.6	164%	-38%	64%	130	32%
WI-13A	111	197	285	2.6	157%	-44%	45%	61	31%
WI-14A	69	168	234	3.4	239%	-59%	39%	60	35%
WI-15A	131	213	367	2.8	180%	-39%	72%	68	32%
WI-16A	238	318	457	1.9	92%	-25%	44%	67	21%
WI-17A	171	311	677	4.0	296%	-45%	118%	151	49%
WI-18A	123	314	504	4.1	310%	-61%	60%	109	35%
WI-19A	177	486	686	3.9	288%	-64%	41%	154	32%
WI-20A	245	583	734	3.0	200%	-58%	26%	164	28%
WI-21A	125	207	321	2.6	157%	-40%	55%	60	29%
WI-22A	188	377	1,396	7.4	643%	-50%	270%	362	96%
WI-23A	29	94	200	6.9	590%	-69%	112%	54	58%
WI-24A	117	209	298	2.5	155%	-44%	43%	69	33%
Average:	131	267	452	4.3	325%	-52%	72%	-	40%

1. See Table 4-9. Relative Percent Difference (RPD) as noted, Standard Deviation (SD) and Relative Standard Deviation (RSD).
2. Percent difference maximum-reported concentration of lead in discrete sample subsamples relative to the minimum-reported concentration [RPD = ((Max-Min)/Min x 100%].
3. Percent difference minimum-reported and maximum-reported concentrations of lead in discrete sample subsamples relative to the mean concentration [e.g., RPD = ((Max-Mean)/Mean x 100%].

Table 4-11. Study Site B lead inter-sample variability data (Method 6010B data).

Sample ID	Lead (mg/kg)										
WI-1A	290	WI-2A	84	WI-3A	310	WI-4A	690	WI-5A	160	WI-6A	300
WI-1B	120	WI-2B	220	WI-3B	330	WI-4B	360	WI-5B	96	WI-6B	98
WI-1C	300	WI-2C	220	WI-3C	320	WI-4C	500	WI-5C	95	WI-6C	310
WI-1D	220	WI-2D	77	WI-3D	410	WI-4D	680	WI-5D	160	WI-6D	300
WI-1E	150	WI-2E	110	WI-3E	420	WI-4E	740	WI-5E	58	WI-6E	270
WI-7A	240	WI-8A	260	WI-9A	110	WI-10A	120	WI-11A	220	WI-12A	410
WI-7B	240	WI-8B	380	WI-9B	94	WI-10B	180	WI-11B	240	WI-12B	200
WI-7C	120	WI-8C	610	WI-9C	160	WI-10C	200	WI-11C	430	WI-12C	300
WI-7D	260	WI-8D	300	WI-9D	98	WI-10D	140	WI-11D	300	WI-12D	590
WI-7E	800	WI-8E	390	WI-9E	96	WI-10E	220	WI-11E	290	WI-12E	500
WI-13A	180	WI-14A	240	WI-15A	230	WI-16A	370	WI-17A	330	WI-18A	380
WI-13B	250	WI-14B	200	WI-15B	300	WI-16B	340	WI-17B	350	WI-18B	270
WI-13C	200	WI-14C	260	WI-15C	220	WI-16C	340	WI-17C	320	WI-18C	200
WI-13D	180	WI-14D	200	WI-15D	210	WI-16D	540	WI-17D	340	WI-18D	310
WI-13E	95	WI-14E	250	WI-15E	250	WI-16E	500	WI-17E	190	WI-18E	620
WI-19A	510	WI-20A	590	WI-21A	270	WI-22A	280	WI-23A	110	WI-24A	310
WI-19B	310	WI-20B	430	WI-21B	170	WI-22B	200	WI-23B	230	WI-24B	240
WI-19C	480	WI-20C	680	WI-21C	170	WI-22C	260	WI-23C	180	WI-24C	250
WI-19D	370	WI-20D	490	WI-21D	240	WI-22D	160	WI-23D	150	WI-24D	300
WI-19E	610	WI-20E	560	WI-21E	170	WI-22E	190	WI-23E	160	WI-24E	270

Table 4-12. Comparison of XRF and Method 6010B (3050B) lead data for Study Site B.

Sample ID	Lead		
	XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference
WI-1A	253	290	-13%
WI-2A	105	84	24%
WI-3A	270	310	-13%
WI-4A	619	690	-10%
WI-5A	121	160	-25%
WI-6A	193	300	-36%
WI-7A	255	240	6.2%
WI-8A	268	260	2.9%
WI-9A	107	110	-3.2%
WI-10A	134	120	12%
WI-11A	217	220	-1.3%
WI-12A	402	410	-2.1%
WI-13A	197	180	9.2%
WI-14A	168	240	-30%
WI-15A	213	230	-7.3%
WI-16A	318	370	-14%
WI-17A	311	330	-5.7%
WI-18A	314	380	-17%
WI-19A	486	510	-4.7%
WI-20A	583	590	-1.2%
WI-21A	207	270	-23%
WI-22A	377	280	35%
WI-23A	94	110	-14%
WI-24A	209	310	-33%
Average:	267	291	-6.8%

Table 4-13. Study Site B summary of lead inter-sample variability¹ (Method 6010B data).

Grid Point	Min (mg/kg)	Mean (mg/kg)	Max (mg/kg)	Max:Min Ratio	²RPD (Max:Min)	SD	RSD
WI-1	120	216	300	2.5	150%	81	37%
WI-2	77	142	220	2.9	186%	72	51%
WI-3	310	358	420	1.4	35%	53	15%
WI-4	360	594	740	2.1	106%	159	27%
WI-5	58	114	160	2.8	176%	45	39%
WI-6	98	256	310	3.2	216%	89	35%
WI-7	120	332	800	6.7	567%	267	81%
WI-8	260	388	610	2.3	135%	136	35%
WI-9	94	112	160	1.7	70%	28	25%
WI-10	120	172	220	1.8	83%	41	24%
WI-11	220	296	430	2.0	95%	82	28%
WI-12	200	400	590	3.0	195%	155	39%
WI-13	95	181	250	2.6	163%	56	31%
WI-14	200	230	260	1.3	30%	28	12%
WI-15	210	242	300	1.4	43%	36	15%
WI-16	340	418	540	1.6	59%	95	23%
WI-17	190	306	350	1.8	84%	66	22%
WI-18	200	356	620	3.1	210%	161	45%
WI-19	310	456	610	2.0	97%	118	26%
WI-20	430	550	680	1.6	58%	96	17%
WI-21	170	204	270	1.6	59%	48	23%
WI-22	160	218	280	1.8	75%	50	23%
WI-23	110	166	230	2.1	109%	44	26%
WI-24	240	274	310	1.3	29%	30	11%
Average:	196	291	403	2.3	126%	-	30%

1. See Table 4-11. Relative Percent Difference (RPD) between maximum- and minimum-reported concentration, Standard Deviation (SD) and Relative Standard Deviation (RSD).

2. Percent difference maximum-reported concentration of lead in co-located discrete samples around individual grid points relative to the minimum-reported concentration [RPD = ((Max-Min)/Min x 100%].

Table 4-14. Study Site B summary of combined lead intra- and inter-sample variability.

Grid Point	¹ Average Lead Concentration		Max:Min Ratio		² Estimated Total Discrete Samples Range			
	Intra-Sample Data (mg/kg)	Inter-Sample Data (mg/kg)	Intra-Sample Variability	Inter-Sample Variability	Adjusted Min (mg/kg)	Adjusted Max (mg/kg)	Max:Min Ratio	³ RPD (Max:Min)
WI-1	253	216	2.0	2.5	83	426	5.1	410%
WI-2	105	142	14.5	2.9	14	581	41.5	4,050%
WI-3	270	358	3.7	1.4	113	570	5.1	406%
WI-4	619	594	3.6	2.1	165	1,212	7.4	637%
WI-5	121	114	3.4	2.8	27	249	9.3	826%
WI-6	193	256	9.1	3.2	21	597	28.7	2,770%
WI-7	255	332	2.0	6.7	78	1,058	13.5	1,253%
WI-8	268	388	4.7	2.3	83	903	10.9	993%
WI-9	107	112	4.6	1.7	34	264	7.9	688%
WI-10	134	172	4.8	1.8	49	435	8.8	783%
WI-11	217	296	1.9	2.0	152	563	3.7	270%
WI-12	402	400	2.6	3.0	125	968	7.8	678%
WI-13	197	181	2.6	2.6	54	363	6.8	576%
WI-14	168	230	3.4	1.3	82	362	4.4	341%
WI-15	213	242	2.8	1.4	129	516	4.0	300%
WI-16	318	418	1.9	1.6	254	776	3.0	205%
WI-17	311	306	4.0	1.8	104	761	7.3	629%
WI-18	314	356	4.1	3.1	78	995	12.7	1,170%
WI-19	486	456	3.9	2.0	113	861	7.6	663%
WI-20	583	550	3.0	1.6	181	857	4.7	374%
WI-21	207	204	2.6	1.6	103	419	4.1	308%
WI-22	377	218	7.4	1.8	80	1,036	13.0	1,199%
WI-23	94	166	6.9	2.1	34	488	14.4	1,342%
WI-24	209	274	2.5	1.3	134	442	3.3	229%
Minimum:	94	112	1.9	1.3	14	249	3.0	205%
Maximum:	619	594	15	6.7	254	1,212	42	4,050%
Mean:	267	291	4.3	2.3	95	654	9.8	879%
Median:	235	265	3.5	2.0	83	576	7.5	650%

1. Intra-sample data based on XRF analysis; inter-sample data based on ICP Method 6010B. XRF data will be lower for lead.
2. Estimated total range of minimum and maximum concentration of lead for hypothetical, discrete soil samples collected within 0.5m of a grid point, based on adjustment of processed sample data (see Table 4-13) downwards and upwards with respect to RPDs measured for intra-sample data set from same grid point (see Table 4-10). Reflects estimates for lab analyzed data; XRF concentrations would be lower (see Table 4-12). For illustration purposes only; accuracy of estimates is uncertain.
3. Relative percent difference between estimated minimum and maximum concentrations of lead in discrete samples within a 0.5m radius of a grid point [RPD = ((Max-Min)/Min x 100%)].

Table 4-15. Study Site C soil grain-size distribution.

Sample ID	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
VOA-1 (1-5)	11%	9.3%	15%	15%	41%	8.8%
VOA-2 (1-5)	1.0%	5.1%	24%	20%	40%	11%
VOA-3 (1-5)	12%	8.2%	10%	13%	49%	7.8%
VOA-4 (1-5)	6.1%	9.5%	30%	23%	27%	4.9%
VOA-5 (1-5)	10%	9.5%	26%	23%	28%	3.5%
VOA-6 (1-5)	22%	14%	16%	16%	25%	5.7%
VOA-7 (1-5)	0.0%	1.5%	6.7%	11%	65%	15%
VOA-8 (1-5)	0.0%	1.6%	10%	13%	57%	18%
VOA-9 (1-5)	0.3%	2.0%	15%	16%	49%	18%
VOA-10 (1-5)	10%	7.3%	14%	18%	45%	6.4%
VOA-11 (1-5)	11%	8.4%	25%	31%	22%	3.0%
VOA-12 (1-5)	27%	21%	21%	15%	11%	4.4%
VOA-13 (1-5)	0.6%	1.7%	9.0%	11%	51%	27%
VOA-14 (1-5)	0.5%	1.0%	5.8%	10%	57%	26%
VOA-15 (1-5)	1.8%	2.6%	21%	23%	37%	15%
VOA-16 (1-5)	5.3%	4.5%	19%	22%	41%	8.8%
VOA-17 (1-5)	9.6%	7.0%	16%	24%	37%	7.4%
VOA-18 (1-5)	18%	13%	22%	19%	23%	5.6%
VOA-19 (1-5)	0.0%	0.0%	3.2%	8.5%	60%	29%
VOA-20 (1-5)	0.0%	0.9%	12%	14%	51%	23%
VOA-21 (1-5)	0.3%	1.6%	12%	14%	49%	24%
VOA-22 (1-5)	2.1%	2.7%	17%	16%	51%	11%
VOA-23 (1-5)	9.1%	5.7%	16%	25%	38%	6.5%
VOA-24 (1-5)	25%	20%	19%	17%	18%	2.3%
Mean (Native Soil):	0.2%	1.2%	8.3%	12%	56%	23%
Mean (Mix):	6.2%	6.8%	21%	19%	37%	9.7%
Mean (Fill):	14%	11%	17%	20%	32%	5.8%

Notes:

1. Native Soil: Samples VOA-7, 8, 13, 14, 19, 20, 21.
2. Mixed Soils: Samples VOA-1, 2, 4, 5, 9, 15, 18, 22.
3. Fill Soil: Samples VOA-3, 6, 10, 11, 12, 16, 17, 23, 24.

Table 4-16. Study Site C PCBs intra-sample variability data.

Sample ID	PCBs (mg/kg)														
VOA-1 (1)	0.56	VOA-2 (1)	7.7	VOA-3 (1)	84	VOA-4 (1)	660	VOA-5 (1)	120	VOA-6 (1)	75	VOA-7 (1)	0.24	VOA-8 (1)	0.19
VOA-1 (2)	1.8	VOA-2 (2)	7.8	VOA-3 (2)	210	VOA-4 (2)	590	VOA-5 (2)	110	VOA-6 (2)	37	VOA-7 (2)	0.27	VOA-8 (2)	22
VOA-1 (3)	1.0	VOA-2 (3)	12	VOA-3 (3)	340	VOA-4 (3)	960	VOA-5 (3)	100	VOA-6 (3)	22	VOA-7 (3)	0.43	VOA-8 (3)	0.39
VOA-1 (4)	2.5	VOA-2 (4)	5.7	VOA-3 (4)	180	VOA-4 (4)	770	VOA-5 (4)	96	VOA-6 (4)	30	VOA-7 (4)	0.40	VOA-8 (4)	0.41
VOA-1 (5)	2.1	VOA-2 (5)	8.3	VOA-3 (5)	140	VOA-4 (5)	1,500	VOA-5 (5)	78	VOA-6 (5)	5.1	VOA-7 (5)	0.29	VOA-8 (5)	0.32
VOA-1 (6)	2.0	VOA-2 (6)	6.1	VOA-3 (6)	230	VOA-4 (6)	1,200	VOA-5 (6)	79	VOA-6 (6)	76	VOA-7 (6)	0.32	VOA-8 (6)	0.28
VOA-1 (7)	2.6	VOA-2 (7)	14	VOA-3 (7)	480	VOA-4 (7)	940	VOA-5 (7)	50	VOA-6 (7)	8.6	VOA-7 (7)	0.33	VOA-8 (7)	0.26
VOA-1 (8)	2.4	VOA-2 (8)	13	VOA-3 (8)	110	VOA-4 (8)	920	VOA-5 (8)	73	VOA-6 (8)	69	VOA-7 (8)	0.20	VOA-8 (8)	0.19
VOA-1 (9)	0.63	VOA-2 (9)	10	VOA-3 (9)	1,000	VOA-4 (9)	790	VOA-5 (9)	34	VOA-6 (9)	37	VOA-7 (9)	0.26	VOA-8 (9)	0.31
VOA-1 (10)	2.0	VOA-2 (10)	12	VOA-3 (10)	190	VOA-4 (10)	890	VOA-5 (10)	130	VOA-6 (10)	90	VOA-7 (10)	0.30	VOA-8 (10)	0.40
VOA-9 (1)	5.6	VOA-10 (1)	6.2	VOA-11 (1)	41	VOA-12 (1)	10,000	VOA-13 (1)	0.17	VOA-14 (1)	0.12	VOA-15 (1)	4.5	VOA-16 (1)	13
VOA-9 (2)	5.6	VOA-10 (2)	5.9	VOA-11 (2)	75	VOA-12 (2)	3,100	VOA-13 (2)	0.17	VOA-14 (2)	0.35	VOA-15 (2)	2.6	VOA-16 (2)	20
VOA-9 (3)	3.6	VOA-10 (3)	6.6	VOA-11 (3)	78	VOA-12 (3)	19,000	VOA-13 (3)	0.25	VOA-14 (3)	0.17	VOA-15 (3)	2.6	VOA-16 (3)	24
VOA-9 (4)	2.0	VOA-10 (4)	13	VOA-11 (4)	49	VOA-12 (4)	10,000	VOA-13 (4)	0.09	VOA-14 (4)	0.18	VOA-15 (4)	1.0	VOA-16 (4)	230
VOA-9 (5)	3.1	VOA-10 (5)	18	VOA-11 (5)	79	VOA-12 (5)	3,900	VOA-13 (5)	0.14	VOA-14 (5)	0.18	VOA-15 (5)	3.9	VOA-16 (5)	150
VOA-9 (6)	3.2	VOA-10 (6)	4.6	VOA-11 (6)	24	VOA-12 (6)	2,600	VOA-13 (6)	3.9	VOA-14 (6)	0.22	VOA-15 (6)	3.9	VOA-16 (6)	21
VOA-9 (7)	2.2	VOA-10 (7)	4.0	VOA-11 (7)	46	VOA-12 (7)	6,700	VOA-13 (7)	0.23	VOA-14 (7)	0.16	VOA-15 (7)	3.5	VOA-16 (7)	13
VOA-9 (8)	11	VOA-10 (8)	6.5	VOA-11 (8)	45	VOA-12 (8)	11,000	VOA-13 (8)	0.21	VOA-14 (8)	0.22	VOA-15 (8)	2.8	VOA-16 (8)	8.8
VOA-9 (9)	2.5	VOA-10 (9)	7.4	VOA-11 (9)	21	VOA-12 (9)	6,800	VOA-13 (9)	1.2	VOA-14 (9)	0.18	VOA-15 (9)	4.3	VOA-16 (9)	14
VOA-9 (10)	1.3	VOA-10 (10)	6.2	VOA-11 (10)	24	VOA-12 (10)	270	VOA-13 (10)	0.15	VOA-14 (10)	0.17	VOA-15 (10)	2.8	VOA-16 (10)	14
VOA-17 (1)	36	VOA-18 (1)	24	VOA-19 (1)	0.04	VOA-20 (1)	0.61	VOA-21 (1)	27	VOA-22 (1)	15	VOA-23 (1)	0.43	VOA-24 (1)	3,100
VOA-17 (2)	17	VOA-18 (2)	11	VOA-19 (2)	0.02	VOA-20 (2)	0.93	VOA-21 (2)	52	VOA-22 (2)	15	VOA-23 (2)	0.70	VOA-24 (2)	1,400
VOA-17 (3)	1.7	VOA-18 (3)	15	VOA-19 (3)	0.04	VOA-20 (3)	0.39	VOA-21 (3)	18	VOA-22 (3)	8.6	VOA-23 (3)	1.8	VOA-24 (3)	5,700
VOA-17 (4)	2.7	VOA-18 (4)	3.5	VOA-19 (4)	0.01	VOA-20 (4)	0.54	VOA-21 (4)	41	VOA-22 (4)	15	VOA-23 (4)	0.55	VOA-24 (4)	3,200
VOA-17 (5)	1.5	VOA-18 (5)	16	VOA-19 (5)	0.10	VOA-20 (5)	0.49	VOA-21 (5)	49	VOA-22 (5)	17	VOA-23 (5)	0.76	VOA-24 (5)	1,000
VOA-17 (6)	10	VOA-18 (6)	15	VOA-19 (6)	0.08	VOA-20 (6)	0.33	VOA-21 (6)	47	VOA-22 (6)	15	VOA-23 (6)	0.25	VOA-24 (6)	2,600
VOA-17 (7)	5.3	VOA-18 (7)	23	VOA-19 (7)	0.05	VOA-20 (7)	0.48	VOA-21 (7)	58	VOA-22 (7)	17	VOA-23 (7)	0.54	VOA-24 (7)	910
VOA-17 (8)	4.1	VOA-18 (8)	15	VOA-19 (8)	0.04	VOA-20 (8)	0.26	VOA-21 (8)	45	VOA-22 (8)	14	VOA-23 (8)	1.3	VOA-24 (8)	810
VOA-17 (9)	7.7	VOA-18 (9)	32	VOA-19 (9)	0.02	VOA-20 (9)	0.27	VOA-21 (9)	36	VOA-22 (9)	18	VOA-23 (9)	1.3	VOA-24 (9)	2,700
VOA-17 (10)	67	VOA-18 (10)	24	VOA-19 (10)	0.07	VOA-20 (10)	1.8	VOA-21 (10)	32	VOA-22 (10)	14	VOA-23 (10)	0.32	VOA-24 (10)	2,700

Table 4-17. Study Site C summary of PCBs intra-sample variability.

Sample ID	Min (mg/kg)	Mean (mg/kg)	Max (mg/kg)	Max:Min Ratio	² RPD (Max:Min)	³ RPD (Min:Mean)	³ RPD (Max:Mean)	SD	RSD
VOA-1 (A)	0.56	1.8	2.6	4.6	364%	-68%	48%	0.76	44%
VOA-2 (A)	5.7	9.6	14	2.5	146%	-41%	45%	3.0	31%
VOA-3 (A)	84	296	1,000	12	1,090%	-72%	237%	273	92%
VOA-4 (A)	590	922	1,500	2.5	154%	-36%	63%	265	29%
VOA-5 (A)	34	87	130	3.8	282%	-61%	49%	30	35%
VOA-6 (A)	5.1	45	90	18	1,665%	-89%	100%	30	67%
VOA-7 (A)	0.20	0.3	0.4	2.2	115%	-34%	41%	0.07	23%
VOA-8 (A)	0.19	2.5	22	116	11,479%	-92%	789%	6.9	277%
VOA-9 (A)	1.3	4.0	11	8.5	746%	-68%	174%	2.8	71%
VOA-10 (A)	4.0	7.8	18	4.5	350%	-49%	130%	4.3	55%
VOA-11 (A)	21	48	79	3.8	276%	-56%	64%	22	47%
VOA-12 (A)	270	7,337	19,000	70	6,937%	-96%	159%	5,441	74%
VOA-13 (A)	0.09	0.7	3.9	44	4,282%	-86%	499%	1.2	182%
VOA-14 (A)	0.12	0.2	0.4	2.9	192%	-38%	79%	0.06	32%
VOA-15 (A)	1.0	3.2	4.5	4.5	350%	-69%	41%	1.0	33%
VOA-16 (A)	8.8	51	230	26	2,514%	-83%	353%	76	149%
VOA-17 (A)	1.5	15	67	45	4,367%	-90%	338%	21	137%
VOA-18 (A)	3.5	18	32	9.1	814%	-80%	79%	8.0	45%
VOA-19 (A)	0.01	0.0	0.1	9.0	800%	-76%	112%	0.03	60%
VOA-20 (A)	0.26	0.6	1.8	6.9	592%	-57%	195%	0.46	76%
VOA-21 (A)	18	41	58	3.2	222%	-56%	43%	12	30%
VOA-22 (A)	8.6	15	18	2.1	109%	-42%	21%	2.6	17%
VOA-23 (A)	0.25	0.8	1.8	7.2	620%	-69%	126%	0.51	64%
VOA-24 (A)	810	2,412	5700	7.0	604%	-66%	136%	1,489	62%
Average:	78	472	1,166	17	1,628%	-66%	163%	-	72%

1. See Table 4-16. Relative Percent Difference (RPD) as noted, Standard Deviation (SD) and Relative Standard Deviation (RSD).
2. Percent difference maximum-reported concentration of PCBs in discrete sample subsamples relative to the minimum-reported concentration [RPD = ((Max-Min)/Min x 100%).
3. Percent difference minimum-reported and maximum-reported concentrations of PCBs in discrete sample subsamples relative to the mean concentration [e.g., RPD = ((Max-Mean)/Mean x 100%).

Table 4-18. Study Site C PCBs inter-sample variability data.

Sample ID	PCBs (mg/kg)										
VOA-1A	1.8	VOA-2A	15	VOA-3A	630	VOA-4A	2,300	VOA-5A	87	VOA-6A	37
VOA-1B	0.71	VOA-2B	15	VOA-3B	63	VOA-4B	310	VOA-5B	110	VOA-6B	45
VOA-1C	0.94	VOA-2C	6.3	VOA-3C	480	VOA-4C	420	VOA-5C	93	VOA-6C	50
VOA-1D	2.4	VOA-2D	16	VOA-3D	62	VOA-4D	2,000	VOA-5D	210	VOA-6D	41
VOA-1E	1.5	VOA-2E	14	VOA-3E	210	VOA-4E	8,400	VOA-5E	96	VOA-6E	34
VOA-7A	0.18	VOA-8A	0.24	VOA-9A	7.4	VOA-10A	26	VOA-11A	9.9	VOA-12A	980
VOA-7B	0.15	VOA-8B	0.16	VOA-9B	9.4	VOA-10B	59	VOA-11B	4.8	VOA-12B	600
VOA-7C	0.18	VOA-8C	0.73	VOA-9C	3.5	VOA-10C	12	VOA-11C	18	VOA-12C	1,100
VOA-7D	0.32	VOA-8D	0.46	VOA-9D	16	VOA-10D	24	VOA-11D	42	VOA-12D	6,100
VOA-7E	0.047	VOA-8E	0.32	VOA-9E	16	VOA-10E	37	VOA-11E	200	VOA-12E	370
VOA-13A	0.37	VOA-14A	0.14	VOA-15A	3.6	VOA-16A	14	VOA-17A	16	VOA-18A	36
VOA-13B	0.60	VOA-14B	0.18	VOA-15B	1.7	VOA-16B	18	VOA-17B	1.9	VOA-18B	26
VOA-13C	1.9	VOA-14C	0.2	VOA-15C	4.6	VOA-16C	16	VOA-17C	40	VOA-18C	33
VOA-13D	0.24	VOA-14D	0.26	VOA-15D	3.6	VOA-16D	12	VOA-17D	16	VOA-18D	29
VOA-13E	0.09	VOA-14E	0.34	VOA-15E	3.6	VOA-16E	22	VOA-17E	47	VOA-18E	36
VOA-19A	0.05	VOA-20A	1.2	VOA-21A	32	VOA-22A	27	VOA-23A	5.2	VOA-24A	7.7
VOA-19B	0.11	VOA-20B	0.43	VOA-21B	26	VOA-22B	15	VOA-23B	8.2	VOA-24B	6.0
VOA-19C	0.054	VOA-20C	1.0	VOA-21C	5.5	VOA-22C	40	VOA-23C	7.5	VOA-24C	91
VOA-19D	0.036	VOA-20D	8.1	VOA-21D	160	VOA-22D	39	VOA-23D	1.5	VOA-24D	14
VOA-19E	0.061	VOA-20E	0.33	VOA-21E	19	VOA-22E	52	VOA-23E	1.8	VOA-24E	4.9

Table 4-19. Study Site C summary of PCBs inter-sample variability¹.

Grid Point	Min (mg/kg)	Mean (mg/kg)	Max (mg/kg)	Max:Min Ratio	²RPD (Max:Min)	SD	RSD
VOA-1	0.71	1.5	2.4	3.4	238%	0.68	46%
VOA-2	6.3	13	16	2.5	154%	4.0	30%
VOA-3	62	289	630	10	916%	256	88%
VOA-4	310	2,686	8,400	27	2,610%	3,318	124%
VOA-5	87	119	210	2.4	141%	51	43%
VOA-6	34	41	50	1.5	47%	6.3	15%
VOA-7	0.05	0.2	0.32	6.8	581%	0.10	56%
VOA-8	0.16	0.4	0.73	4.6	356%	0.22	59%
VOA-9	3.5	10	16	4.6	357%	5.5	52%
VOA-10	12	32	59	4.9	392%	18	56%
VOA-11	4.8	55	200	42	4,067%	82	150%
VOA-12	370	1,830	6,100	16	1,549%	2,405	131%
VOA-13	0.09	0.6	1.9	20	1,943%	0.73	114%
VOA-14	0.14	0.2	0.34	2.4	143%	0.08	35%
VOA-15	1.7	3.4	4.6	2.7	171%	1.1	31%
VOA-16	12	16	22	1.8	83%	3.8	23%
VOA-17	1.9	24	47	25	2,374%	19	77%
VOA-18	26	32	36	1.4	38%	4.4	14%
VOA-19	0.04	0.1	0.11	3.1	206%	0.03	45%
VOA-20	0.33	2.2	8.1	25	2,355%	3.3	150%
VOA-21	5.5	49	160	29	2,809%	63	130%
VOA-22	15	35	52	3.5	247%	14	41%
VOA-23	1.5	4.8	8.2	5.5	447%	3.1	64%
VOA-24	4.9	25	91	19	1,757%	37	151%
Average:	40	220	671	11	999%	-	72%

1. See Table 4-18. Relative Percent Difference (RPD) between maximum- and minimum-reported concentration, Standard Deviation (SD) and Relative Standard Deviation (RSD).

2. Percent difference maximum-reported concentration of PCBs in co-located discrete samples around individual grid points relative to the minimum-reported concentration [RPD = ((Max-Min)/Min x 100%].

Table 4-20. Study Site C summary of combined PCBs intra- and inter-sample variability.

Grid Point	Average PCB Concentration		Max:Min Ratio		¹ Estimated Total Discrete Sample Range			
	Subsampled Discrete (mg/kg)	Processed Discretes (mg/kg)	Intra-Sample Variability	Inter-Sample Variability	Adjusted Min (mg/kg)	Adjusted Max (mg/kg)	Max:Min Ratio	² RPD (Max:Min)
VOA-1	1.8	1.5	4.6	3.4	0.23	3.6	16	1,469%
VOA-2	9.6	13	2.5	2.5	3.7	23	6.2	524%
VOA-3	296	289	12	10	18	2,126	121	11,997%
VOA-4	922	2,686	2.5	27	198	13,666	69	6,789%
VOA-5	87	119	3.8	2.4	34	314	9.2	823%
VOA-6	45	41	18	1.5	3.9	100	26	2,495%
VOA-7	0.30	0.18	2.2	6.8	0.03	0.45	15	1364%
VOA-8	2.5	0.38	116	4.6	0.01	6.5	528	52,729%
VOA-9	4.0	10	8.5	4.6	1.1	44	39	3,768%
VOA-10	7.8	32	4.5	4.9	6.1	135	22	2,113%
VOA-11	48	55	3.8	42	2.1	328	157	15,575%
VOA-12	7,337	1,830	70	16	14	15,797	1,160	115,916%
VOA-13	0.65	0.64	44	20	0.01	11	895	89,425%
VOA-14	0.20	0.22	2.9	2.4	0.09	0.61	7.1	608%
VOA-15	3.2	3.4	4.5	2.7	0.53	6.5	12	1,118%
VOA-16	51	16	26	1.8	2.1	100	48	4,692%
VOA-17	15	24	45	25	0.19	206	1,105	110,391%
VOA-18	18	32	9.1	1.4	5.1	65	13	1,166%
VOA-19	0.05	0.06	9.0	3.1	0.01	0.23	28	2,650%
VOA-20	0.61	2.2	6.9	25	0.14	24	170	16,893%
VOA-21	41	49	3.2	29	2.4	229	94	9,274%
VOA-22	15	35	2.1	3.5	8.7	63	7.3	626%
VOA-23	0.80	4.8	7.2	5.5	0.47	19	39	3,836%
VOA-24	2,412	25	7.0	19	1.6	215	131	12,969%
Minimum:	0.05	0.06	2.1	1.4	0.01	0.23	6.2	5.2
Maximum:	7,337	2,686	116	42	198	15,797	1,160	1,159
Mean:	472	220	17	11	13	1395	197	196
Median:	12	20	7.0	4.7	1.9	63.8	39.0	38.0

1. Estimated total range of minimum and maximum concentration of PCBs for hypothetical, discrete soil samples collected within 0.5m of a grid point, based on adjustment of measured minimum and maximum concentrations for processed samples (see Table 4-19) downwards and upwards with respect to RPDs for minimum and maximum concentrations measured for intra-sample data set from same grid relative to the mean for that data set (see Table 4-17). For illustration purposes only; accuracy of estimates is uncertain.

2. Relative percent difference between estimated minimum and maximum concentrations of PCBs in discrete samples within a 0.5m radius of a grid point [RPD = ((Max-Min)/Min x 100%].

Table 4-21. Study Site C summary of combined PCBs intra- and inter-sample variability by soil type.

Grid Point	⁴ Average PCB Concentration		⁴ Median Max:Min Ratio		⁴ Estimated Total Discrete Sample Variability			
	Subsampled Discretes (mg/kg)	Processed Discretes (mg/kg)	Intra-Sample Variability	Inter-Sample Variability	Minimum Max:Min Ratio	Maximum Max:Min Ratio	Median Max:Min Ratio	⁴ Median RPD
¹ Native Soils:	6.4	7.5	6.9	6.8	7.08	895	94	9,274%
² Mixed Soils:	133	363	4.2	3.0	6.2	69	12	1,166%
³ Fill Soils:	1,135	257	12	10	22	1,160	121	11,997%
All Soil Types:	472	220	7.0	4.7	0.01	1,160	39	3,802%

1. Native Soil: Samples VOA-7, 8, 13, 14, 19, 20, 21.

2. Mixed Soils: Samples VOA-1, 2, 4, 5, 9, 15, 18, 22.

3. Fill Soil: Samples VOA-3, 6, 10, 11, 12, 16, 17, 23, 24.

4. See Table 4-20. Estimated range of PCB concentration variability discrete samples collected within a 0.5m radius of a grid point based on combined intra-sample and inter-sample variability. For illustration purposes only; accuracy of estimates is uncertain.

Table 5-1. Summary of intra- and inter-sample variability at study sites.

Study Site	¹ Median Intra-Sample Variability	¹ Median Inter-Sample Variability	Estimated Total Variability		Range RPD
			² Median Max:Min Ratio	³ Median RPD (Max:Min)	
Site A (arsenic)	1.4	1.3	2.0	96%	29% to 308%
Site B (lead)	3.5	2.0	7.5	650%	205% to 4,050%
⁴ Site C (PCBs) (native soil)	6.9	6.8	94	9,274%	608% to 89,425%
⁴ Site C (PCBs) (mixed soils)	4.2	3.0	12	1,142%	524% to 6,789%
⁴ Site C (PCBs) (fill soil)	12	10	121	11,997%	2,113% to 115,916%
⁴ Site C (PCBs) (combined)	7.0	4.7	39	3,802%	524% to 115,916%

1. Variability measured as ratio of maximum to minimum-reported concentration of the contaminant within (intra-sample) and between co-located (inter-sample) discrete samples collected around grid points. Refer to summary tables for noted study site.
2. Multiple of median intra- and inter-sample variability.
3. Estimated, median Relative Percent Difference between estimated minimum and maximum concentrations of discrete samples collected within a 0.5m radius of a grid point.
4. See Figure 2-10 and Table 4-15 for sample soil types.

Table 5-2. Mean PCB concentration for Subsamples 6-10 of Study Site C intra-sample variability data set (see also Table 4-16).

Sample ID	PCBs (mg/kg)														
VOA-1 (6)	2.0	VOA-2 (6)	6.1	VOA-3 (6)	230	VOA-4 (6)	1,200	VOA-5 (6)	79	VOA-6 (6)	76	VOA-7 (6)	0.32	VOA-8 (6)	0.28
VOA-1 (7)	2.6	VOA-2 (7)	14	VOA-3 (7)	480	VOA-4 (7)	940	VOA-5 (7)	50	VOA-6 (7)	8.6	VOA-7 (7)	0.33	VOA-8 (7)	0.26
VOA-1 (8)	2.4	VOA-2 (8)	13	VOA-3 (8)	110	VOA-4 (8)	920	VOA-5 (8)	73	VOA-6 (8)	69	VOA-7 (8)	0.20	VOA-8 (8)	0.19
VOA-1 (9)	0.63	VOA-2 (9)	10	VOA-3 (9)	1,000	VOA-4 (9)	790	VOA-5 (9)	34	VOA-6 (9)	37	VOA-7 (9)	0.26	VOA-8 (9)	0.31
VOA-1 (10)	2.0	VOA-2 (10)	12	VOA-3 (10)	190	VOA-4 (10)	890	VOA-5 (10)	130	VOA-6 (10)	90	VOA-7 (10)	0.30	VOA-8 (10)	0.40
Ave PCBs:	1.9	Ave PCBs:	11	Ave PCBs:	402	Ave PCBs:	948	Ave PCBs:	73	Ave PCBs:	56	Ave PCBs:	0.28	Ave PCBs:	0.29
VOA-9 (6)	3.2	VOA-10 (6)	4.6	VOA-11 (6)	24	VOA-12 (6)	2,600	VOA-13 (6)	3.9	VOA-14 (6)	0.22	VOA-15 (6)	3.9	VOA-16 (6)	21
VOA-9 (7)	2.2	VOA-10 (7)	4.0	VOA-11 (7)	46	VOA-12 (7)	6,700	VOA-13 (7)	0.23	VOA-14 (7)	0.16	VOA-15 (7)	3.5	VOA-16 (7)	13
VOA-9 (8)	11	VOA-10 (8)	6.5	VOA-11 (8)	45	VOA-12 (8)	11,000	VOA-13 (8)	0.21	VOA-14 (8)	0.22	VOA-15 (8)	2.8	VOA-16 (8)	8.8
VOA-9 (9)	2.5	VOA-10 (9)	7.4	VOA-11 (9)	21	VOA-12 (9)	6,800	VOA-13 (9)	1.2	VOA-14 (9)	0.18	VOA-15 (9)	4.3	VOA-16 (9)	14
VOA-9 (10)	1.3	VOA-10 (10)	6.2	VOA-11 (10)	24	VOA-12 (10)	270	VOA-13 (10)	0.15	VOA-14 (10)	0.17	VOA-15 (10)	2.8	VOA-16 (10)	14
Ave PCBs:	4.0	Ave PCBs:	5.7	Ave PCBs:	32	Ave PCBs:	5,474	Ave PCBs:	1.1	Ave PCBs:	0.19	Ave PCBs:	3.5	Ave PCBs:	14
VOA-17 (6)	10	VOA-18 (6)	15	VOA-19 (6)	0.08	VOA-20 (6)	0.33	VOA-21 (6)	47	VOA-22 (6)	15	VOA-23 (6)	0.25	VOA-24 (6)	2,600
VOA-17 (7)	5.3	VOA-18 (7)	23	VOA-19 (7)	0.05	VOA-20 (7)	0.48	VOA-21 (7)	58	VOA-22 (7)	17	VOA-23 (7)	0.54	VOA-24 (7)	910
VOA-17 (8)	4.1	VOA-18 (8)	15	VOA-19 (8)	0.04	VOA-20 (8)	0.26	VOA-21 (8)	45	VOA-22 (8)	14	VOA-23 (8)	1.3	VOA-24 (8)	810
VOA-17 (9)	7.7	VOA-18 (9)	32	VOA-19 (9)	0.02	VOA-20 (9)	0.27	VOA-21 (9)	36	VOA-22 (9)	18	VOA-23 (9)	1.3	VOA-24 (9)	2,700
VOA-17 (10)	67	VOA-18 (10)	24	VOA-19 (10)	0.07	VOA-20 (10)	1.8	VOA-21 (10)	32	VOA-22 (10)	14	VOA-23 (10)	0.32	VOA-24 (10)	2,700
Ave PCBs:	19	Ave PCBs:	22	Ave PCBs:	0.05	Ave PCBs:	0.63	Ave PCBs:	44	Ave PCBs:	16	Ave PCBs:	0.74	Ave PCBs:	1,944

Table 5-3. Comparison of TPH and PCB data for discrete soil samples collected at Study Site C.

Grid Point	¹ PCBs (mg/kg)	² C10-C28 (mg/kg)	³ Other TPH Data		
			C10-C44 (mg/kg)	C29-C40 (mg/kg)	C41-C44 (mg/kg)
VOA-1	1.9	17	93	64	<2.5
VOA-2	11	89	440	290	56
VOA-3	402	150	230	64	<2.5
VOA-4	948	600	820	150	<50
VOA-5	73	100	240	120	<2.5
VOA-6	56	53	150	74	<2.5
VOA-7	0.28	8.1	36	20	2.9
VOA-8	0.29	6.6	26	14	<2.5
VOA-9	4.0	6.6	23	12	<2.5
VOA-10	5.7	15	58	33	5.3
VOA-11	32	39	110	59	<2.4
VOA-12	5,474	4,300	6,600	470	<240
VOA-13	1.1	9.9	41	24	<2.5
VOA-14	0.19	9.7	56	39	<2.5
VOA-15	3.5	8.7	43	26	<2.5
VOA-16	14	19	59	29	4.3
VOA-17	19	21	71	39	5.5
VOA-18	22	160	710	480	<9.6
VOA-19	0.05	7.6	23	9.1	<2.5
VOA-20	0.63	7.9	36	21	<2.5
VOA-21	44	37	68	24	2.5
VOA-22	16	17	52	26	<2.5
VOA-23	0.74	8.0	46	29	2.9
VOA-24	1,944	350	1,300	870	<20

1. Average total PCB concentration for Subsamples 6 through 10 of noted grid point sample (see Table 5-2).
2. Total Petroleum Hydrocarbons measured as Diesel Range Organics (C10-C28).
3. Total Petroleum Hydrocarbons measured Extractable Fuel Hydrocarbons (C10-C44), Residual Range Organics (C29-C40) and C41-C44. Total TPH as sum of carbon ranges does not add up to EFH due to differences in analytical methods.

Table 5-4. Summary of average ¹particle-size distribution at study sites.

Study Site	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay
Site A (arsenic)	0.2%	0.7%	16%	63%	4.0%	16%
Site B (lead)	14%	11%	31%	33%	7.9%	3.0%
Site C (PCBs) (native soil)	0.2%	1.2%	8.3%	12%	56%	23%
Site C (PCBs) (mixed)	5.6%	6.4%	22%	20%	36%	9.8%
Site C (PCBs) (fill)	14%	11%	18%	22%	30%	5.5%

1. Particle-size ranges:

Gravel, passing 75mm sieve and retained on No. 4 sieve (4.75mm);

Sand, passing No. 4 sieve and retained on No. 200 sieve (0.95mm);

Coarse sand, passing No. 4 sieve and retained on No. 10 sieve (2mm);

Medium sand, passing No. 10 sieve and retained on No. 40 sieve (425µm);

Fine sand, passing No. 40 sieve and retained on No. 200 sieve (75µm);

Silt size, <75µm to ≥5µm;

Clay size, <5µm.

Table 5-5. Average particle size distribution for <2mm soil fraction (normalized to 100%).

Study Site	Medium Sand	Fine Sand	Silt	Clay
Site A (arsenic)	16%	64%	4.0%	16%
Site B (lead)	41%	44%	11%	4.0%
Site C (PCBs) (native soil)	8.4%	12%	56%	23%
Site C (PCBs) (mixed)	25%	23%	41%	11%
Site C (PCBs) (fill)	24%	28%	40%	7.3%

Table 5-6. ¹Particle-size distribution in <2mm fraction of soil versus intra-sample variability for Study Site C.

Soil Type	² Sample ID	³ Average PCBs (mg/kg)	Silt+Clay	Fine Sand	Medium	⁴ Intra-Sample Variability
Native Clayey Silts	VOA-7 (1-5)	0.3	82%	11%	7%	2.2
	VOA-8 (1-5)	2.5	76%	13%	10%	116
	VOA-13 (1-5)	0.7	80%	11%	9%	44
	VOA-14 (1-5)	0.2	84%	10%	6%	2.9
	VOA-19 (1-5)	0.05	88%	9%	3%	9.0
	VOA-20 (1-5)	0.6	74%	14%	12%	6.9
	VOA-21 (1-5)	41	74%	14%	12%	3.2
Mix Native and Fill Soils	VOA-1 (1-5)	1.8	62%	19%	19%	4.6
	VOA-2 (1-5)	9.6	53%	21%	26%	2.5
	VOA-4 (1-5)	922	38%	27%	35%	2.5
	VOA-5 (1-5)	87	39%	29%	32%	3.8
	VOA-9 (1-5)	4.0	68%	17%	15%	8.5
	VOA-15 (1-5)	3.2	55%	24%	22%	4.5
	VOA-18 (1-5)	18	41%	27%	31%	9.1
	VOA-22 (1-5)	15	65%	17%	18%	2.1
Fill Soil	VOA-3 (1-5)	296	71%	16%	13%	12
	VOA-6 (1-5)	45	49%	25%	26%	18
	VOA-10 (1-5)	7.8	62%	21%	16%	4.5
	VOA-11 (1-5)	48	31%	38%	31%	3.8
	VOA-12 (1-5)	7,337	30%	29%	41%	70
	VOA-16 (1-5)	51	55%	24%	21%	26
	VOA-17 (1-5)	15	53%	28%	19%	45
	VOA-23 (1-5)	0.8	52%	29%	19%	7.2
	VOA-24 (1-5)	2,412	37%	30%	33%	7.0

Notes

1. Particle size distribution discounting gravel; assumed to reflect subsample actually tested by the laboratory (see Table 4-13).
2. Samples sorted with respect to total fraction of silt and clay particles.
3. Average PCB concentration reported for subsamples (refer to Table 4-15).
4. Ratio of maximum to minimum concentration of PCBs for ten, 10g subsamples tested from individual discrete samples (see Table 4-15).

Table 5-7. Summary of MIS replicate data for study sites.

Study Site	Replicate A (mg/kg)	Replicate B (mg/kg)	Replicate C (mg/kg)	Mean (mg/kg)	Standard Deviation (mg/kg)	Relative Standard Deviation	Student's t 95% UCL (mg/kg)	Chebyshev 95% UCL (mg/kg)
Site A (arsenic)	220	250	230	233	15	6.5%	259	272
Site B (lead)	240	270	350	287	57	20%	383	430
Site C (PCBs)	270	24	19	104	143	138%	346	467

Table 5-8. Comparison of mass and number of sample points represented by discrete versus incremental data sets.

Data Set	¹Number of Sample Location Grid Points Represented	²Number of Samples/ Increments Collected per Grid Point	³Approximate Mass of Soil Represented per Grid Point (grams)	⁴Total Mass of Soil Represented by Analysis (grams)	⁶Total Number of Analyses	⁷Study Site A Mean Arsenic Concentration (mg/kg)	⁷Study Site B Mean Lead Concentration (mg/kg)	⁷Study Site C Mean PCB Concentration (mg/kg)
⁵Intra-Sample Variability Data	24	1	10 (100)	240 (2,400)	240	369 (255)	267 (285)	472
Inter-Sample Variability Data	24	5	1,000	24,000	120	240	291	220
Multi Increment[®] Data	180	1	25	4,500	3	233	287	104

1. Number of grid points for discrete sample data sets and number of increment collection points for MI sample data sets noted. Total number of increments for Study Site C presented (total increment represented by triplicate MI samples); fifty-four increment MI samples collected at Study Sites A and B.

2. Intra-Sample data set reflects ten independent analyses of one, unprocessed sample per grid point.

3. Intra-Sample Data Set = Total approximate mass of soil tested per grid point (ten, one-gram subsamples per grid point); Inter-Sample Data Set = Total approximate mass of processed samples per grid point (five 200g samples per point); MIS Data = Approximate mass of increment collected at each grid point).

4. Intra-Sample and Inter-Sample Data Sets = Approximate mass of soil represented per point times total number of points; MIS Data Set = Total mass of processed, replicate samples (three approximately 1.5kg samples per site).

5. Ten grams of soil represented per grid point for Study Sites A and B (arsenic and lead XRF data; 1g per analysis); 100g of soil represented per grid point for Study Site C (PCBs, 10g per analysis). Numbers in parentheses for intra-sample data represent downward adjustment of arsenic mean by 31% to reflect positive bias of XRF in comparison to 6010B data in inter-sample and MI data sets and upward adjustment of lead mean by 6.8% to reflect negative bias in XRF vs 6010B data (see Sections 4.1 and 4.2).

6. Number of independent XRF or laboratory analyses carried out per study site for noted data set; ten per grid point for intra-sample discrete data

7. Mean contaminant concentration calculated for data set.

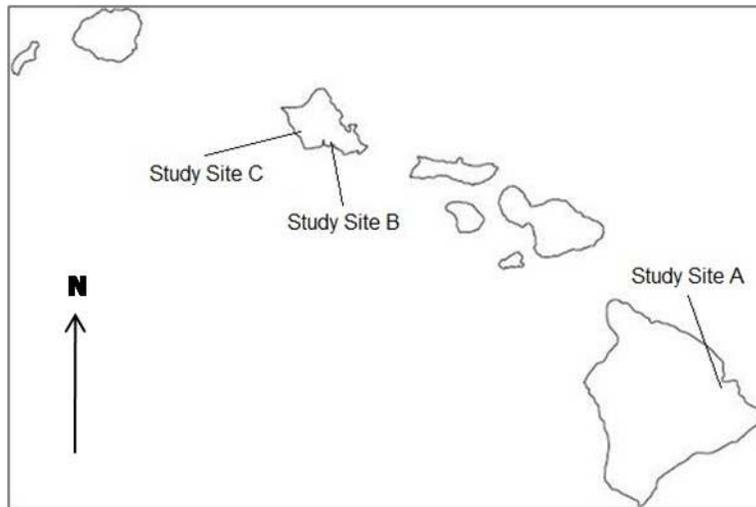


Figure 2-1. Location of study sites.



Figure 2-2. Location of Study Site A in Wailoa State Park in Hilo, Hawai'i.

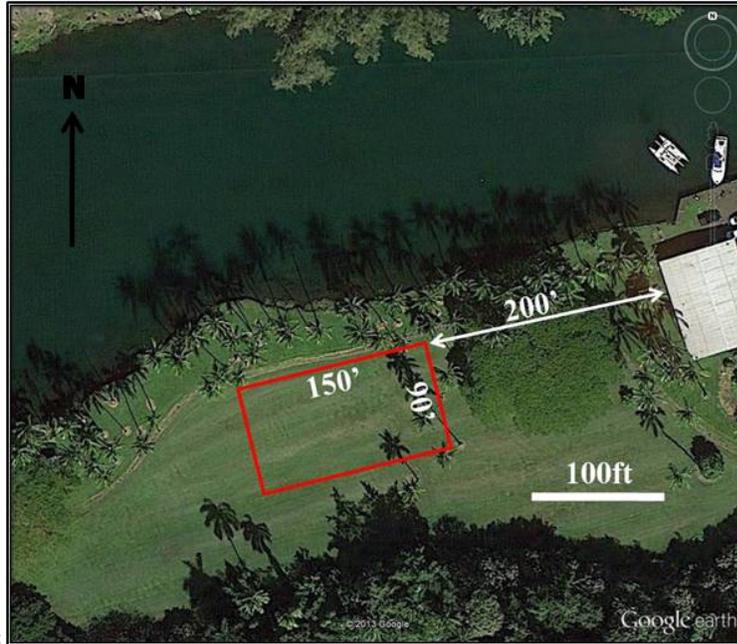


Figure 2-3. Open, grass-covered area in the northeastern area of Wailoa State Park selected for sample collection.

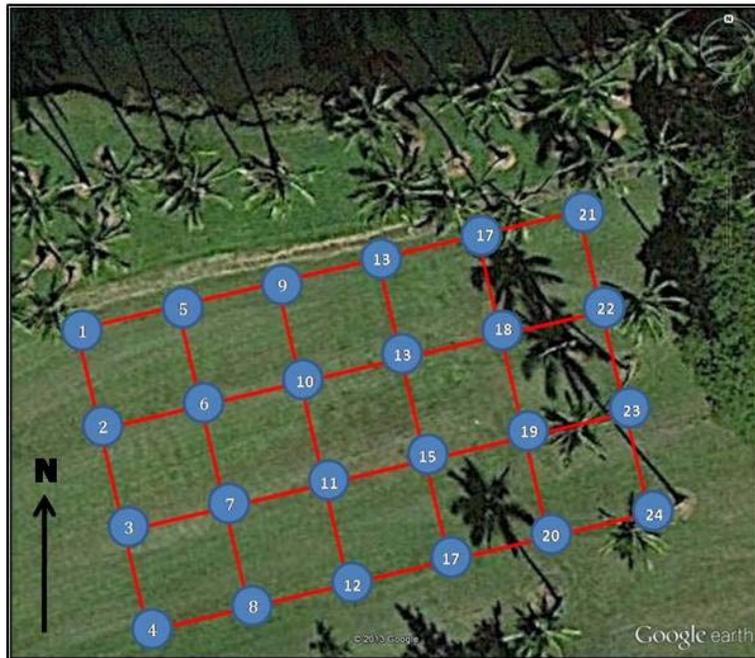


Figure 2-4. Sample grid for Wailoa State Park study site.



Figure 2-5. Location of the former Waipahu incinerator site in Waipahu, O'ahu.

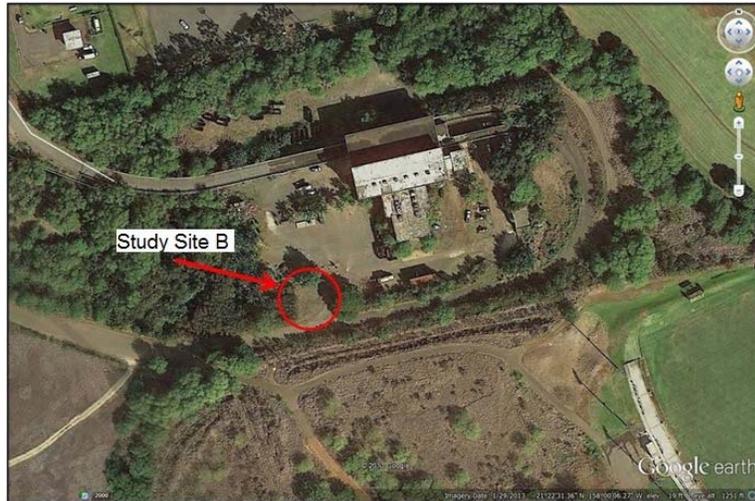


Figure 2-6. Open area by makai (south) gate of former incinerator facility selected for sample collection.

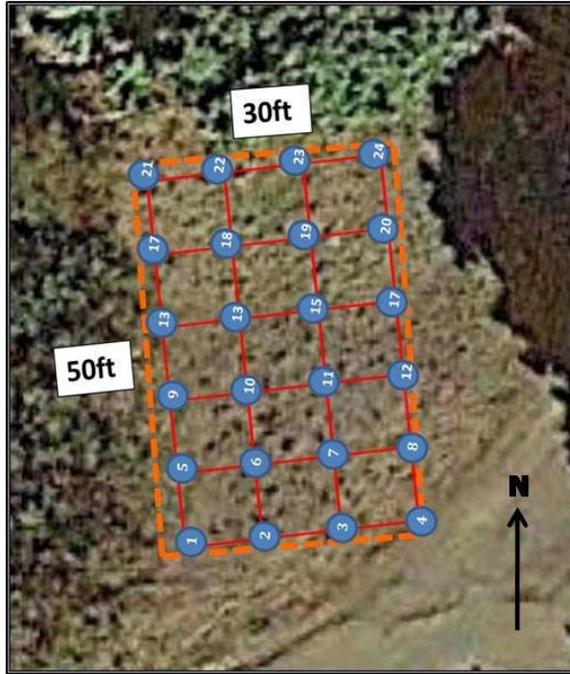


Figure 2-7. Sample grid for former Waipahu incinerator study site.



Figure 2-8. Location of the former Voice of America site in Maʻili Oʻahu.



Figure 2-9. Open area on north side of former transmitter building selected for sample collection (building slabs visible in photo).

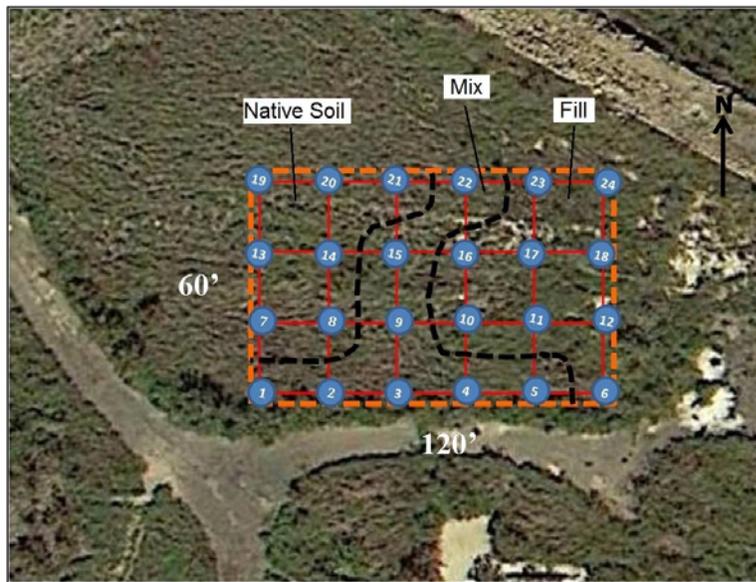


Figure 2-10. Sample grid for former Voice of America study site depicting soil types (soil type boundaries approximate).

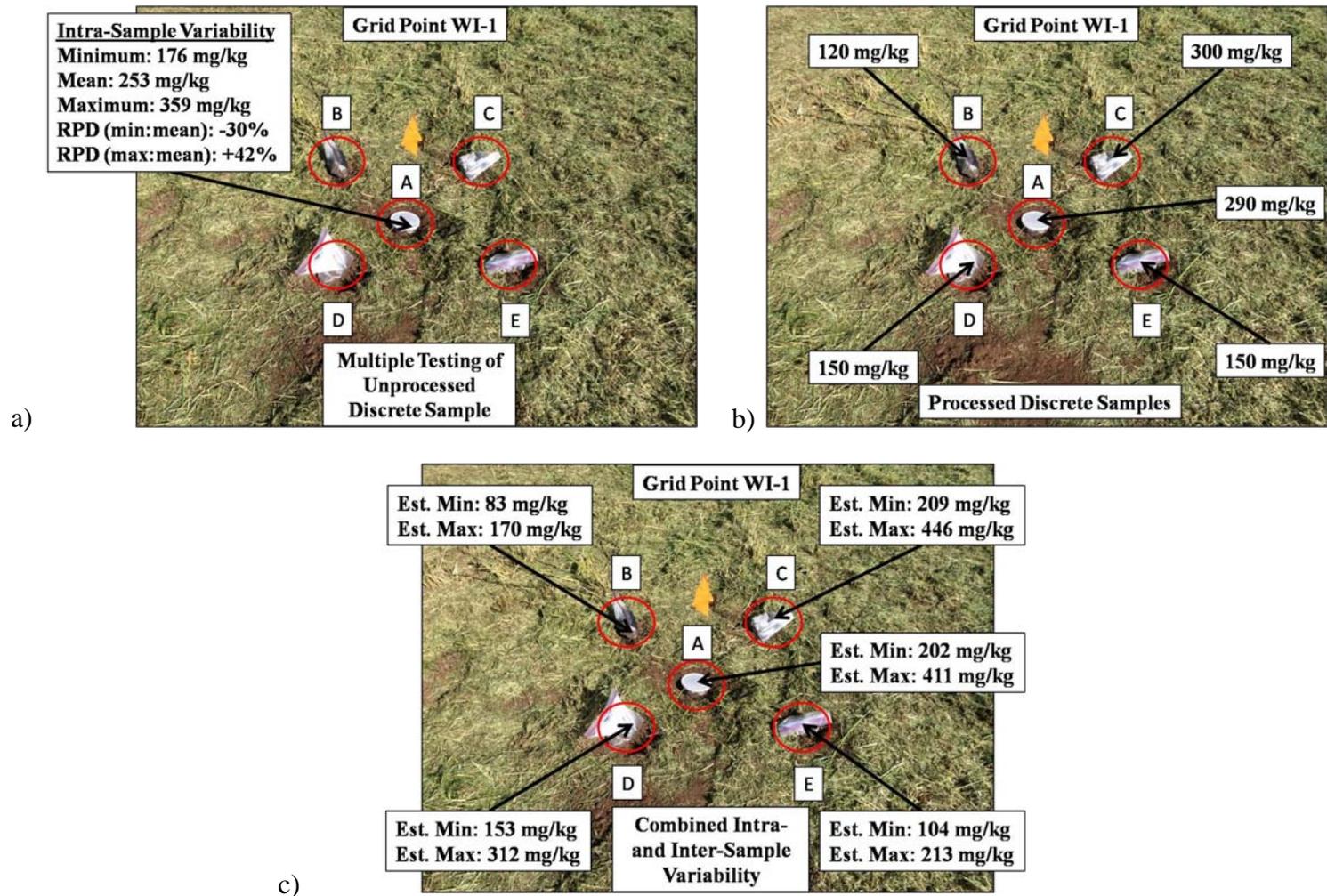


Figure 4-1. Estimation of total, discrete sample variability around grid points: a) Relative Percent Difference (RPD) of minimum- and maximum-reported concentration for intra-sample data set calculated; b) Reported concentration for processed samples assumed to reflect mean for sample; c) Minimum and Maximum RPDs applied to processed samples to estimate total range of discrete sample concentration around grid point.

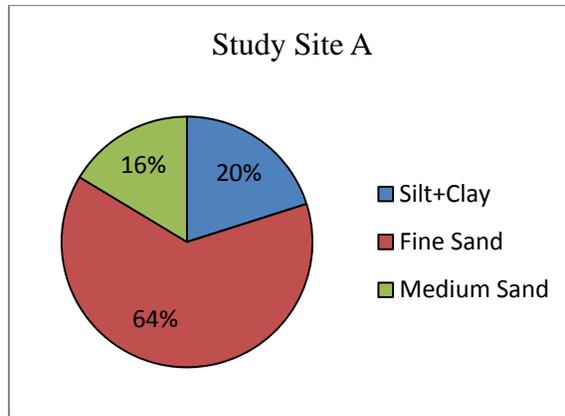


Figure 4-2. Average grain size distribution of <2mm soil fraction at Study Site A.

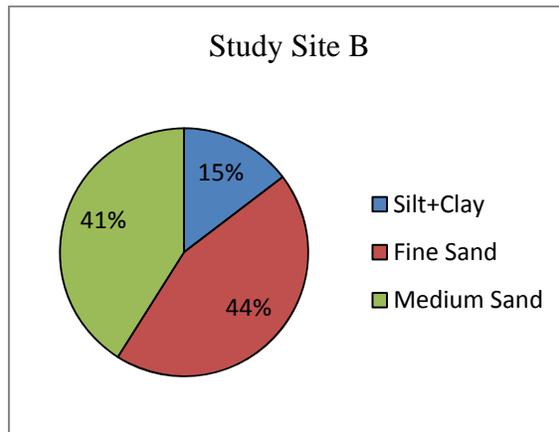


Figure 4-3. Average grain size distribution of <2mm soil fraction at Study Site B.

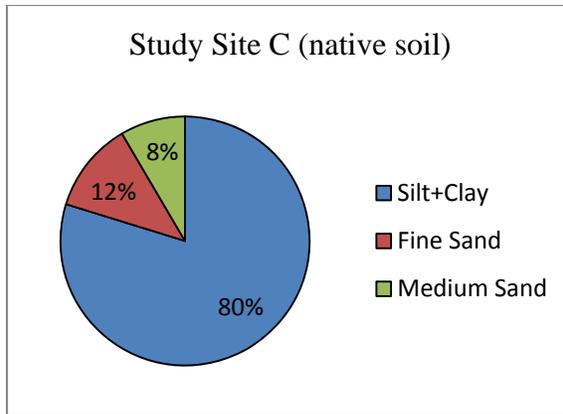


Figure 4-4. Average grain size distribution of <2mm native soil fraction at Study Site C.

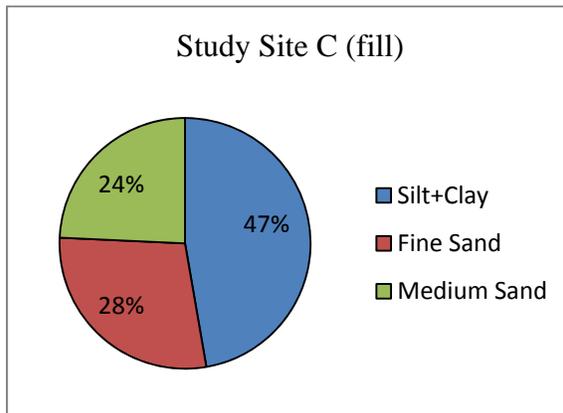


Figure 4-5. Average grain size distribution of <2mm fill soil fraction at Study Site C.

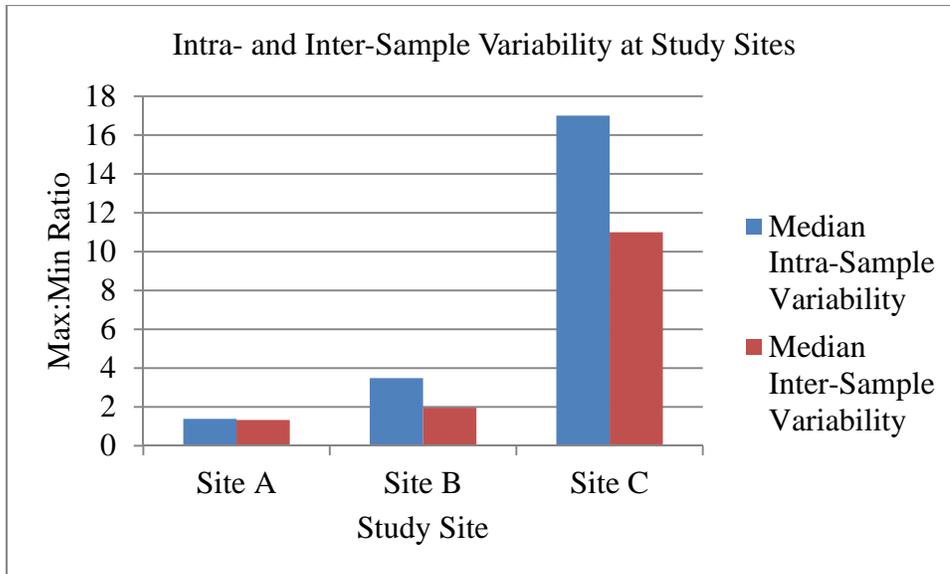


Figure 5-1. Summary of intra- and inter-sample variability calculated for the study sites, based on the ratio of the maximum- to minimum-reported concentration of contaminants within samples (“intra-sample”) or between co-located sets of samples (“inter-sample”).

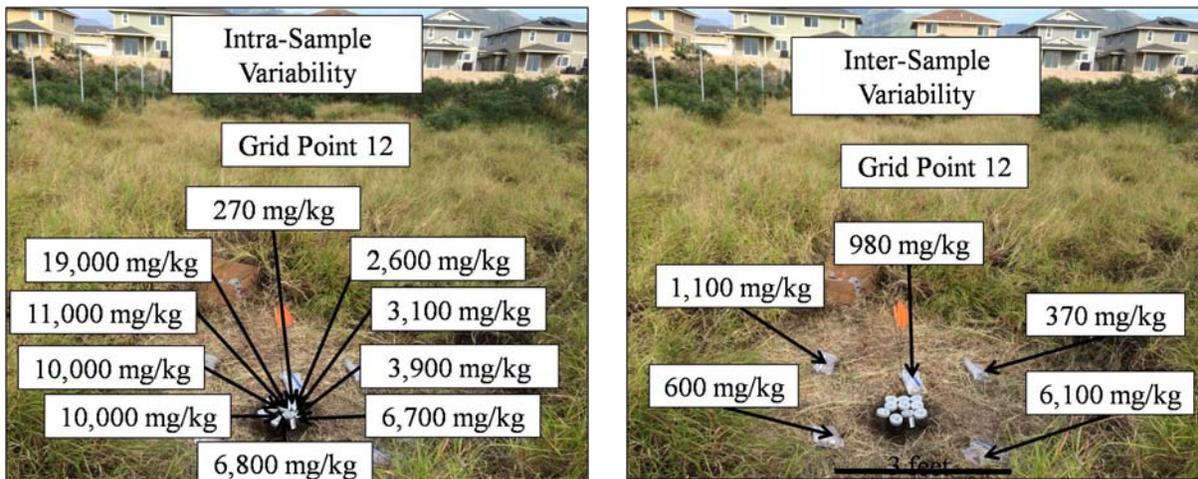


Figure 5-2. Depiction of intra-sample and inter-sample variability of PCB concentrations at a grid point location in Study Site C.



Figure 5-3. Droplets of olive oil formed on dry flour. Note paths left by retreating oil to form more compact, higher standing droplets.

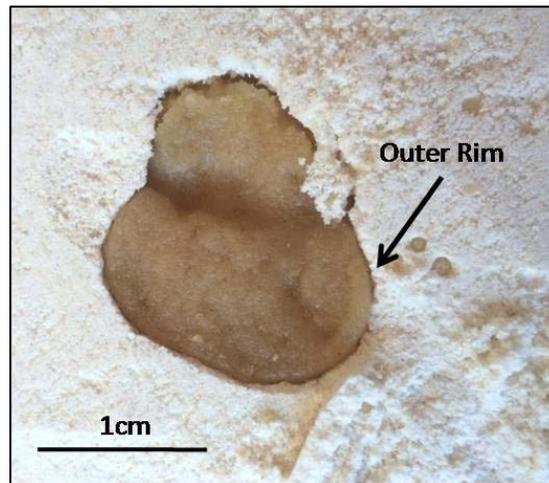


Figure 5-4. Migration of olive oil droplet into dry flour over a period of several minutes. Note the distinct, thin rim that forms around the outer perimeter the resulting clump of oil-saturated flour that represents the remnant of the droplet.

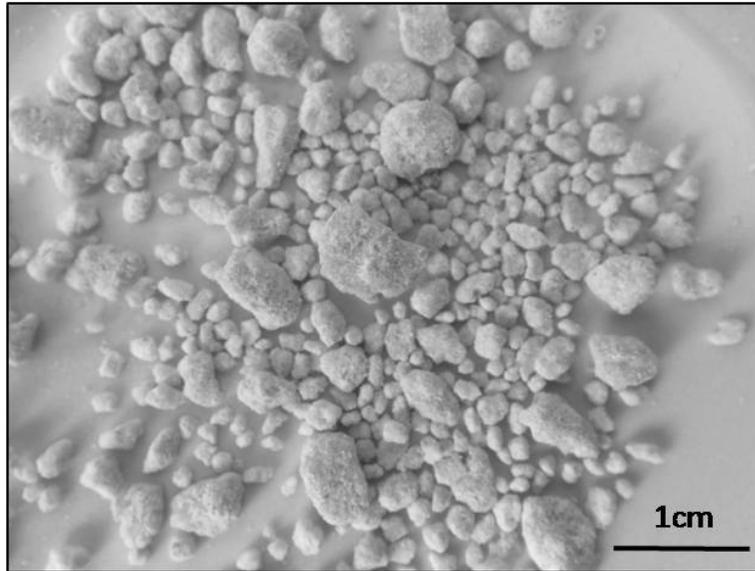


Figure 5-5. Olive oil-infused nuggets sieved from dry flour (see Figure 5-3).

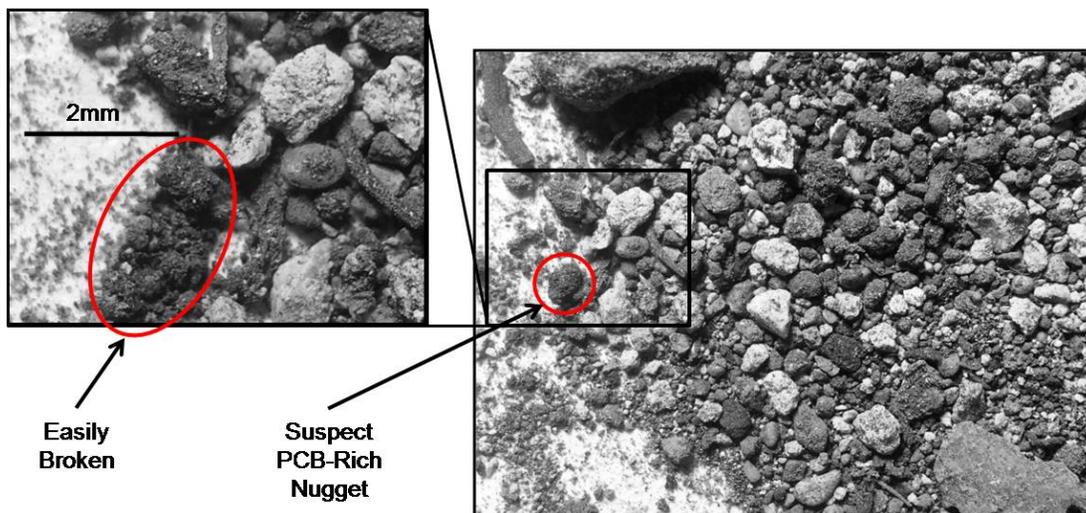


Figure 5-6. Suspect PCB oil-infused nuggets of soil identified in soil sample VOA-12 (8) from Study Site C. Clump was easily crushed when lightly pressed with a knife and coarse-grained, distinguishing them from rock fragments and aggregates of clay.

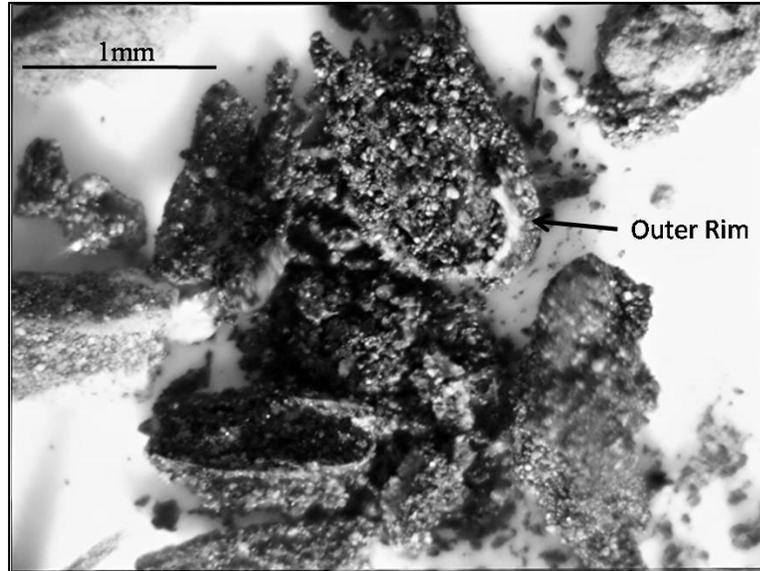


Figure 5-7. Photomicrograph of possible PCB-infused nugget of silty soil at Study Site C, representing a remnant drop of waste oil released to the surface (Sample VOA-12 (8); different nugget from that shown in Figure 5-6). Note granular nature of interior material and distinct, thin, light-colored rim around the outer perimeter of the clump with darker material adhered to the outside.

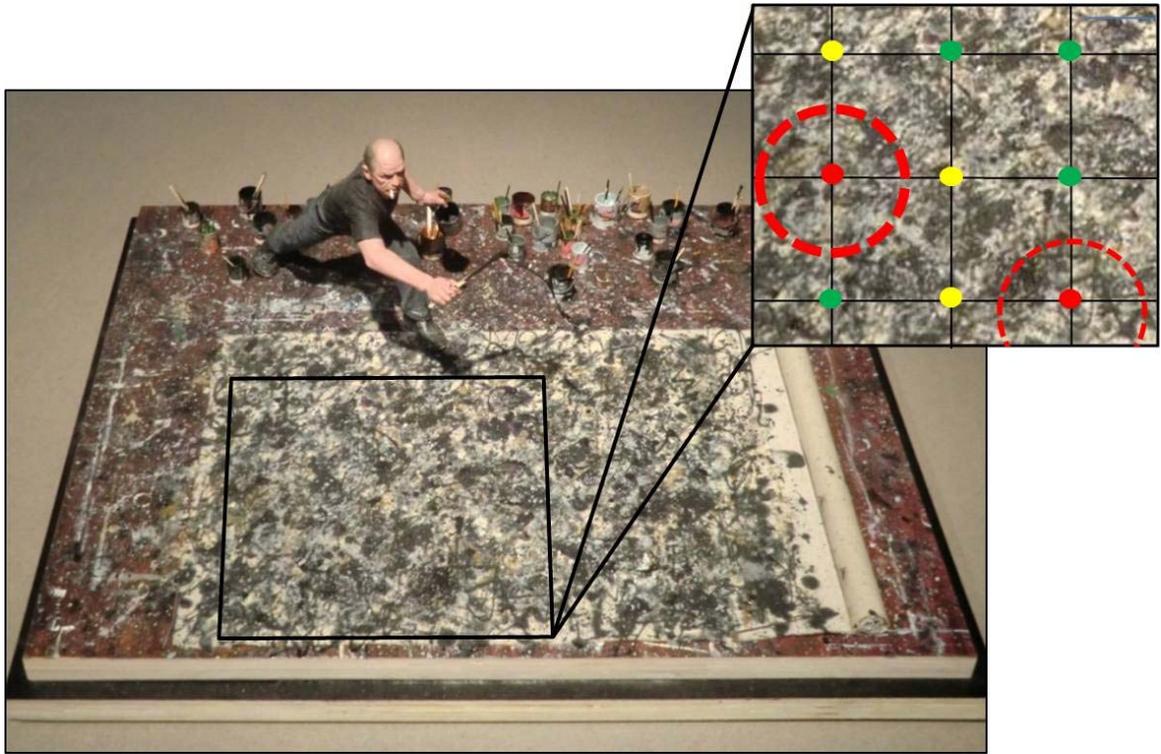


Figure 5-8. Misleading “hot spots” and “cold spots” identified in Jackson Pollock painting with hypothetically discrete samples within an otherwise area of heavy “contamination.” Paint splatters form droplets on canvas. Sample dots approximate size of typical discrete sample (200g); mass actually tested by laboratory significantly smaller (one to thirty grams).



Figure 5-9. Irregular and disconnected spill patterns on soil made by a release of milk. This might also mimic vertical patterns for subsurface releases of liquids.

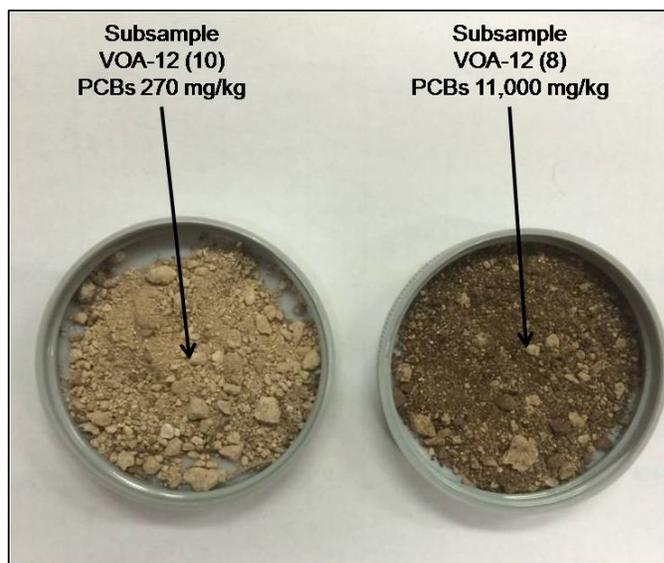


Figure 5-10. Two distinct soil types encountered within subsamples of the discrete sample collected from a 10cm radius area at Study Site C, Grid Point 12 in order to evaluate intra-sample variability. The reported concentration of PCBs was noticeably lower in the subsample dominated by light-colored, coralline soil (left photo, VOA-12 (10)) than in subsamples dominated by reddish brown, more clay and silt-rich soil (e.g., right photo, Sample VOA-12 (8); see also Table 16 in Part 1).

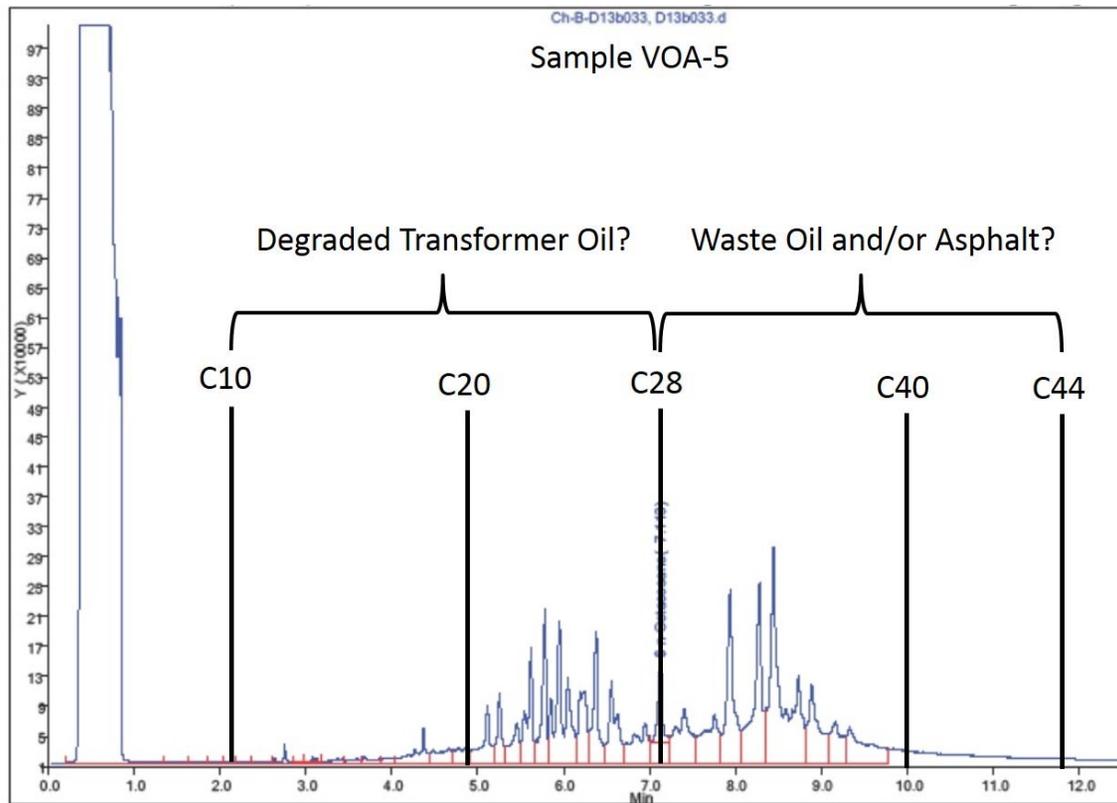


Figure 5-11. Chromatogram for TPH analysis of combined Subsamples 6-10 collected around Grid Point 5 at Study Site depicting apparent mix of degraded transformer oil and heavier waste oil and/or asphalt (Sample VOA-5; refer to Table 5-3).

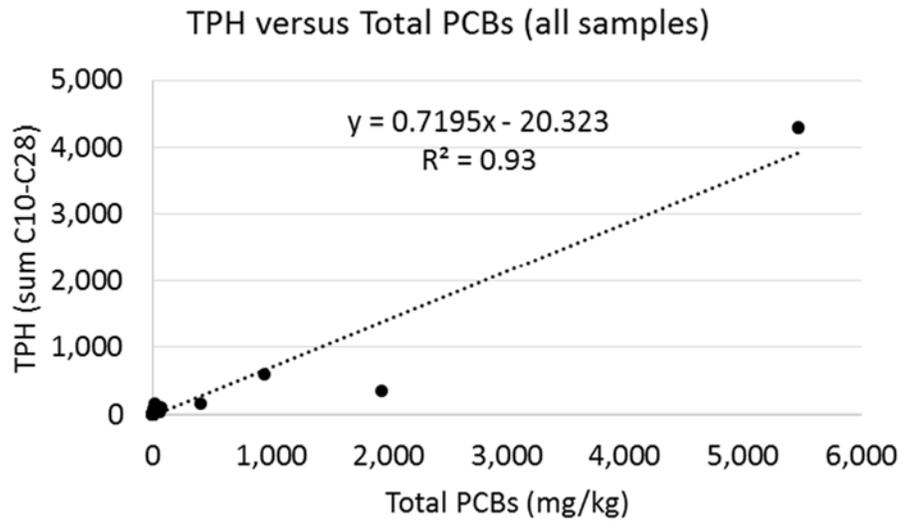


Figure 5-12a. Correlation of TPH vs total PCBs reported for discrete samples from Study Site C (data for all samples included; see Table 5-3).

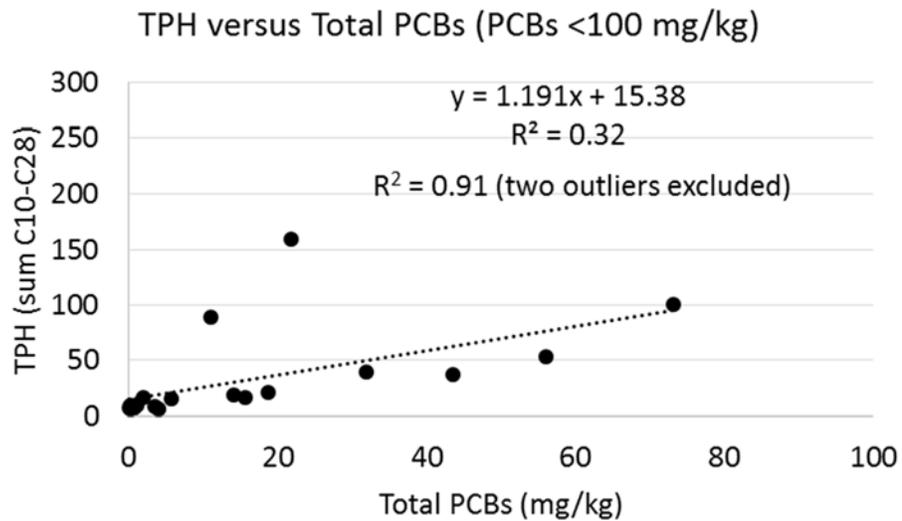


Figure 5-12b. Correlation of TPH vs total PCBs reported for discrete samples from Study Site C with total PCBs <100 mg/kg (see Table 5-3). Note two outlier sample points; an R^2 value of 0.91 is generated when these points are excluded.

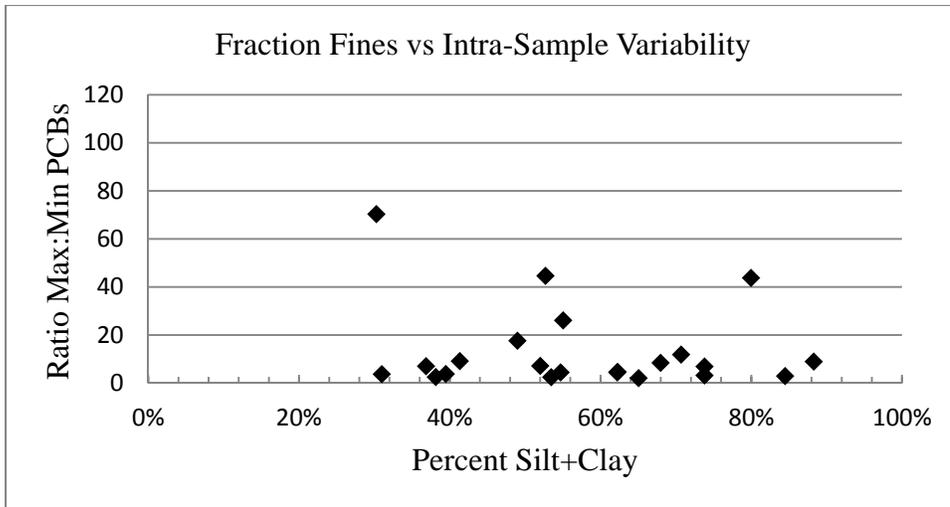


Figure 5-13. Fraction fines versus intra-sample variability of PCB concentrations at Study Site C.

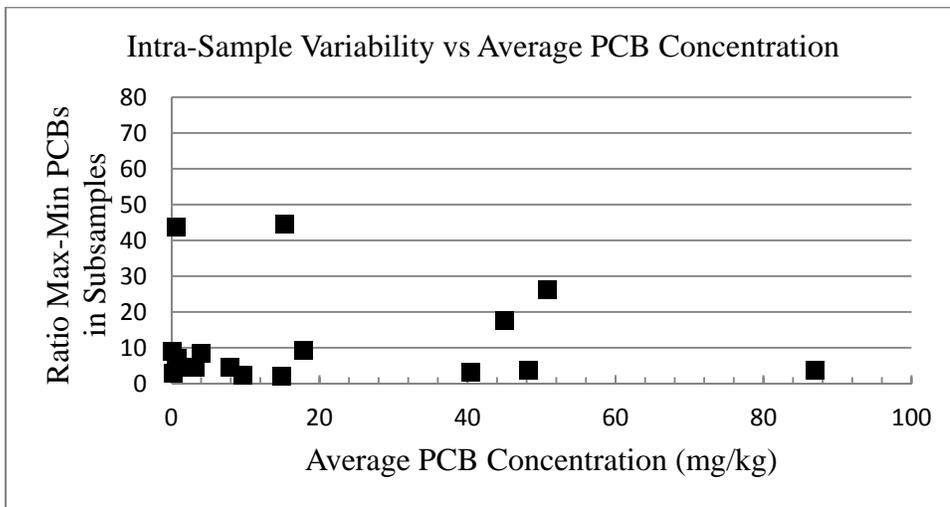


Figure 5-14a. Intra-sample variability versus PCB concentrations at Study Site C (0-100 mg/kg PCBs samples).

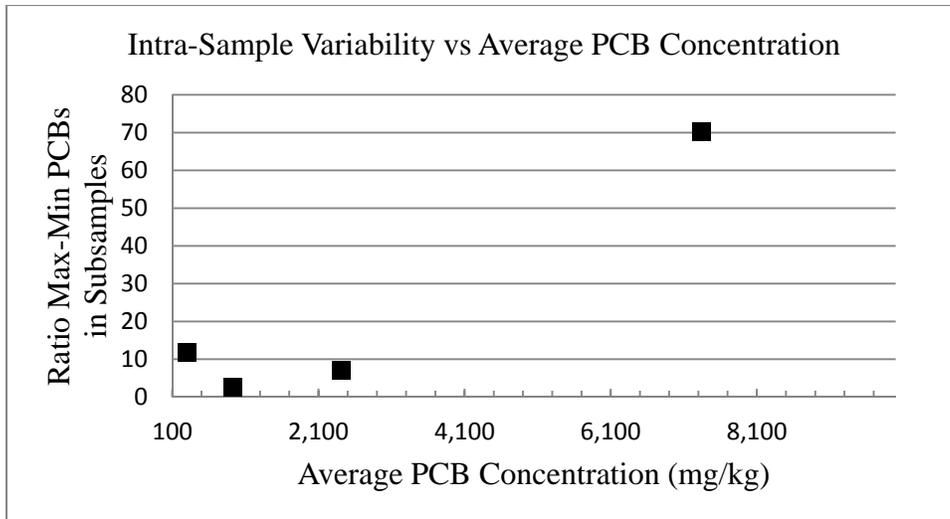


Figure 5-14b. Intra-sample variability versus PCB concentrations at Study Site C (>100 mg/kg PCBs samples).

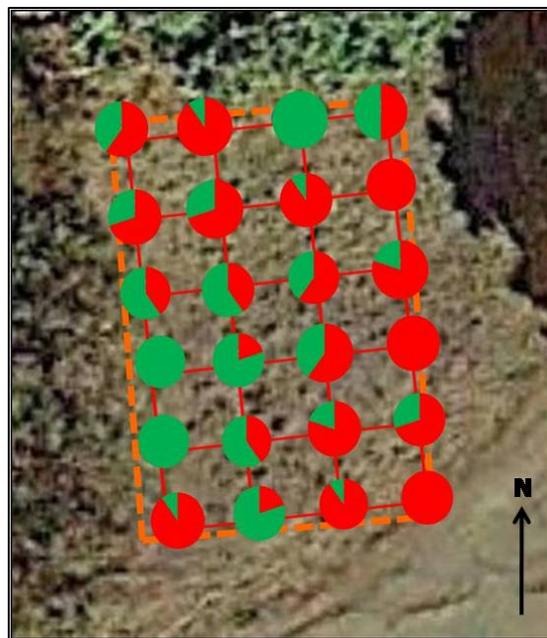


Figure 6-1. Fraction of XRF lead readings above and below HDOH residential soil action level of 200 mg/kg at for grid points at Study Site B (see Table 4-9).



Photo 2-1. Study Site A – Northeast corner of Wailoa State Park and adjacent to Waiakea pond in Hilo (looking north); flags denote increment locations used for collection of MI samples.



Photo 2-2. Prescreening of arsenic concentration and variability in surface soil at Study Site A with a portable XRF (Marvin Heskett, Geotek-Hawai'i).



Photo 2-3. Study Site B – South (makai) side of former Waipahu incinerator on O'ahu (looking northeast).



Photo 2-4. Study Site C – Former Voice of America broadcasting station in Ma'ili on O'ahu (looking east).



Photo 3-1. Sample collection locations at grid point for Study Site A at Wailoa State Park in Hilo.



Photo 3-2. Collection of discrete samples from Study Site B (Jordan Nakayama, HDOH, and Eric Wetzstein, AMEC-Hawai'i).



Photo 3-3. Samples collected from corner and center of grid point at Study Site B; center sample placed in plastic container with minimal disturbance for XRF analysis.



Photo 3-4. Collection of discrete soil samples from grid points at Study Site C (Jordan Nakayama, HDOH, and Matt Neal, Element Environmental).



Photo 3-5. Collection of discrete sample subsamples in separate jars (total ten) at Study Site C grid point for individual analysis (Roger Brewer, HDOH).



Photos 3-6. Discrete sample set for grid point at Study Site C, including five samples for processing in individual bags and sixth sample placed in ten separate jars (subsamples) from analysis without processing.



Photo3-7. Conclusion of field work at Study Site C and end of field portion of study (Jordan Nakayama and John Peard, HDOH).



Photo 3-8. Multi Increment samples (triplicates) collected from Study Site A.



Photo 3-9. Testing of undisturbed, discrete sample from Study Site A with portable XRF at Geotek-Hawai'i office.

Appendices:

Appendix 1: Laboratory reports (electronic only)

Appendix 2: XRF Analytical Reports

Appendix 3: Comparison of XRF vs Method 6010B (3050B) Data

Appendix 2: XRF Analytical Reports



GeoTek Hawaii, Inc.
Geophysical and Environmental Site Assessment

Analytical Report

FOR

Roger Brewer
Hawaii Department of Health
Hazard Evaluation and Emergency Response
919 Ala Moana Boulevard, Room 206
Honolulu, HI 96814

PROJECT

Waialoa Arsenic Heterogeneity Study

PO 1097591

GeoTek Hawaii Project # HR13-0090Ar1

Reported on: 9/12/13

Reviewed by:

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Senior Chemist

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Client: HDOH HEER
Project: Waialoa Arsenic Heterogeneity Study
GTH Project#: HR13-0090Ar1

Discussion

Narrative

GeoTek Hawaii(GTH) analyzed samples provided by HDOH HEER from Wailoa Park using a field portable X-ray fluorescence detector (XRF) on September 2 through 5, 2013. 24 samples were analyzed in replicate 10 times for a total of 240 separate results. Samples were analyzed in a manner similar to EPA method 6200.

Samples were analyzed from plastic containers mimicking an *in situ* condition using an Olympus Delta 2000 standard XRF with a 4 watt x-ray tube and silicon drift detector. Field calibration standards, blanks and spikes were used for QA/QC measures. The analyst was trained in the use of the device and in radiation safety.

Prior to field mobilization, DOH HEER provided GTH a field sample to test matrix suitability. The sample was collected during rainfall typical of the Hilo area on 8/14/13. Soil moisture is known to interfere with XRF readings. GTH took 9 separate XRF readings with an average of 82mg/kg and a moisture content of 38%. The sample was dried and analyzed again with an average concentration of 146mg/kg, confirming that field moisture was suitable for XRF analysis. Furthermore, GTH sieved the dried sample through a 250µm screen, re-analyzed the sample and spiked an additional 500mg/kg As. The resulting site specific reference sample or field matrix spike has a theoretical value of 667mg/kg and was used throughout the study to confirm instrument performance.

The instrument was calibrated daily using a 318 stainless steel coin as per manufacturer specs. Following the calibration a NIST silicon blank was analyzed to confirm negative control. The field matrix spike was analyzed to confirm positive control and a NIST standard reference material, SRM2711a was confirmed twice daily at the beginning and end of each batch. 7 replicates were analyzed by taking readings from the same sample location to confirm method precision.

Samples were prepared by opening the top of the sample container and placing a thin plastic sheet marked with 5 evenly spaced sample locations directly on the soil. Measurements were taken at each of 5 marks and the sample was turned over, pressed out of the container onto a clean plastic sheet and the process was repeated on the bottom side of the sample. Using this technique, readings were taken at ground surface and at approximately 2" below ground surface.

A portion of each sample was removed to perform a percent moisture calculation. Final sample results are dry weight corrected using air dried moisture results.

Data is presented in the following tables.

Example XRF spectra, photographs of the sample preparation and a copy of the Chain of Custody are provided in the Appendix.

Client: DOH HEER

Project: **Waialoa Arsenic Heterogeneity Study**

GTH ID: HR13-0090Ar1

Analytical Results

Date	Time	Sample ID	Run #	Unit	moisture	Fe	As	Ni	Cu	Zn
9/3/2013	16:15:42	WLP-1a	1	mg/kg-dry	54%	107580	255	102	63	181
9/3/2013	16:16:24	WLP-1a	2	mg/kg-dry	54%	104750	250	131	48	200
9/3/2013	16:17:02	WLP-1a	3	mg/kg-dry	54%	113696	274	131	46	198
9/3/2013	16:17:39	WLP-1a	4	mg/kg-dry	54%	101775	259	126	44	183
9/3/2013	16:18:13	WLP-1a	5	mg/kg-dry	54%	109203	276	154	65	213
9/3/2013	16:19:35	WLP-1a	6	mg/kg-dry	54%	142784	331	146	76	231
9/3/2013	16:20:10	WLP-1a	7	mg/kg-dry	54%	147921	346	183	85	233
9/3/2013	16:20:46	WLP-1a	8	mg/kg-dry	54%	148709	342	168	104	235
9/3/2013	16:21:22	WLP-1a	9	mg/kg-dry	54%	143124	335	157	81	228
9/3/2013	16:21:57	WLP-1a	10	mg/kg-dry	54%	134397	322	181	78	213
9/3/2013	16:28:27	WLP-2a	1	mg/kg-dry	36%	79496	144	89	42	110
9/3/2013	16:29:03	WLP-2a	2	mg/kg-dry	36%	105905	172	102	64	135
9/3/2013	16:29:38	WLP-2a	3	mg/kg-dry	36%	90859	165	80	31	100
9/3/2013	16:30:14	WLP-2a	4	mg/kg-dry	36%	104537	161	135	63	121
9/3/2013	16:30:52	WLP-2a	5	mg/kg-dry	36%	99203	165	108	49	132
9/3/2013	16:32:13	WLP-2a	6	mg/kg-dry	36%	114675	196	154	49	132
9/3/2013	16:32:47	WLP-2a	7	mg/kg-dry	36%	119433	172	197	58	143
9/3/2013	16:33:23	WLP-2a	8	mg/kg-dry	36%	120588	199	177	61	143
9/3/2013	16:34:00	WLP-2a	9	mg/kg-dry	36%	94467	169	102	61	125
9/3/2013	16:34:35	WLP-2a	10	mg/kg-dry	36%	117704	204	172	55	147
9/3/2013	16:42:53	WLP-3a	1	mg/kg-dry	56%	111423	541	76	80	216
9/3/2013	16:43:29	WLP-3a	2	mg/kg-dry	56%	107534	500	80	92	223
9/3/2013	16:44:06	WLP-3a	3	mg/kg-dry	56%	106653	454	122	39	181
9/3/2013	16:44:46	WLP-3a	4	mg/kg-dry	56%	130334	587	209	64	234
9/3/2013	16:45:48	WLP-3a	5	mg/kg-dry	56%	163507	633	223	94	289
9/3/2013	16:46:24	WLP-3a	6	mg/kg-dry	56%	145043	691	172	119	278
9/3/2013	16:47:02	WLP-3a	7	mg/kg-dry	56%	152819	642	298	101	280
9/3/2013	16:47:37	WLP-3a	8	mg/kg-dry	56%	147999	656	190	101	273
9/3/2013	16:48:18	WLP-3a	9	mg/kg-dry	56%	140819	601	135	94	255
9/9/2013	12:29:10	WLP-3a	10	mg/kg-dry	56%	138798	615	177	89	264
9/3/2013	16:52:51	WLP-4a	1	mg/kg-dry	62%	137067	637	232	107	210
9/3/2013	16:53:27	WLP-4a	2	mg/kg-dry	62%	146820	719	218	85	221
9/3/2013	16:54:03	WLP-4a	3	mg/kg-dry	62%	113140	554	120	67	192
9/3/2013	16:54:38	WLP-4a	4	mg/kg-dry	62%	146301	733	216	96	237
9/3/2013	16:55:14	WLP-4a	5	mg/kg-dry	62%	125900	615	144	83	208
9/3/2013	16:56:14	WLP-4a	6	mg/kg-dry	62%	221714	1412	163	91	237
9/3/2013	16:56:50	WLP-4a	7	mg/kg-dry	62%	186427	876	197	120	274
9/3/2013	16:57:26	WLP-4a	8	mg/kg-dry	62%	185817	884	229	101	261
9/3/2013	16:58:02	WLP-4a	9	mg/kg-dry	62%	213807	765	290	117	288
9/3/2013	16:58:38	WLP-4a	10	mg/kg-dry	62%	189502	815	202	88	285
9/4/2013	13:35:34	WLP-5a	1	mg/kg-dry	66%	133478	544	113	92	226

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Date	Time	Sample ID	Run #	Unit	moisture	Fe	As	Ni	Cu	Zn
9/4/2013	13:36:10	WLP-5a	2	mg/kg-dry	66%	120537	538	131	92	208
9/4/2013	13:36:44	WLP-5a	3	mg/kg-dry	66%	164583	677	226	101	270
9/4/2013	13:37:20	WLP-5a	4	mg/kg-dry	66%	134688	559	169	80	253
9/4/2013	13:37:56	WLP-5a	5	mg/kg-dry	66%	141755	573	163	71	253
9/4/2013	13:39:17	WLP-5a	6	mg/kg-dry	66%	170243	674	247	98	288
9/4/2013	13:40:01	WLP-5a	7	mg/kg-dry	66%	176544	701	238	110	300
9/4/2013	13:40:44	WLP-5a	8	mg/kg-dry	66%	171826	695	250	104	276
9/4/2013	13:41:23	WLP-5a	9	mg/kg-dry	66%	194773	873	190	113	303
9/4/2013	13:41:58	WLP-5a	10	mg/kg-dry	66%	184797	740	303	116	297
9/4/2013	13:44:53	WLP-6a	1	mg/kg-dry	45%	103582	363	102	62	173
9/4/2013	13:45:42	WLP-6a	2	mg/kg-dry	45%	99410	351	102	55	169
9/4/2013	13:46:24	WLP-6a	3	mg/kg-dry	45%	112130	378	158	62	191
9/4/2013	13:47:26	WLP-6a	4	mg/kg-dry	45%	95290	340	140	45	147
9/4/2013	13:48:04	WLP-6a	5	mg/kg-dry	45%	97114	353	105	64	162
9/4/2013	13:49:12	WLP-6a	6	mg/kg-dry	45%	123514	416	140	67	193
9/4/2013	13:49:55	WLP-6a	7	mg/kg-dry	45%	122958	423	149	69	184
9/4/2013	13:50:33	WLP-6a	8	mg/kg-dry	45%	113626	394	142	55	189
9/4/2013	13:51:13	WLP-6a	9	mg/kg-dry	45%	108983	374	162	73	164
9/4/2013	13:51:49	WLP-6a	10	mg/kg-dry	45%	115334	394	211	56	180
9/4/2013	13:58:10	WLP-7a	1	mg/kg-dry	54%	131754	183	130	59	235
9/4/2013	13:58:48	WLP-7a	2	mg/kg-dry	54%	119745	176	104	67	228
9/4/2013	13:59:31	WLP-7a	3	mg/kg-dry	54%	133151	185	146	85	233
9/4/2013	14:00:08	WLP-7a	4	mg/kg-dry	54%	117845	165	117	54	224
9/4/2013	14:00:47	WLP-7a	5	mg/kg-dry	54%	110769	172	93	59	239
9/4/2013	14:01:47	WLP-7a	6	mg/kg-dry	54%	145095	187	120	87	254
9/4/2013	14:02:28	WLP-7a	7	mg/kg-dry	54%	146053	217	120	57	254
9/4/2013	14:03:06	WLP-7a	8	mg/kg-dry	54%	146155	189	161	78	267
9/4/2013	14:03:45	WLP-7a	9	mg/kg-dry	54%	153316	206	187	89	256
9/4/2013	14:04:25	WLP-7a	10	mg/kg-dry	54%	139829	193	150	70	265
9/4/2013	14:07:26	WLP-8a	1	mg/kg-dry	48%	112179	233	95	52	137
9/4/2013	14:08:13	WLP-8a	2	mg/kg-dry	48%	129317	270	183	48	154
9/4/2013	14:09:01	WLP-8a	3	mg/kg-dry	48%	102081	212	77	37	118
9/4/2013	14:09:47	WLP-8a	4	mg/kg-dry	48%	114972	237	91	29	147
9/4/2013	14:10:38	WLP-8a	5	mg/kg-dry	48%	112154	218	177	52	145
9/4/2013	14:11:43	WLP-8a	6	mg/kg-dry	48%	121481	264	77	52	145
9/4/2013	14:12:20	WLP-8a	7	mg/kg-dry	48%	135702	282	120	77	174
9/4/2013	14:12:59	WLP-8a	8	mg/kg-dry	48%	126123	295	162	69	145
9/4/2013	14:13:43	WLP-8a	9	mg/kg-dry	48%	143027	260	154	50	160
9/4/2013	14:14:20	WLP-8a	10	mg/kg-dry	48%	142817	299	191	56	160
9/4/2013	14:19:14	WLP-9a	1	mg/kg-dry	58%	118774	565	130	94	174
9/4/2013	14:19:58	WLP-9a	2	mg/kg-dry	58%	99602	528	<20	71	160
9/4/2013	14:20:38	WLP-9a	3	mg/kg-dry	58%	90225	480	78	61	158
9/4/2013	14:21:19	WLP-9a	4	mg/kg-dry	58%	105087	499	146	75	170
9/4/2013	14:22:01	WLP-9a	5	mg/kg-dry	58%	86579	478	90	61	158

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Date	Time	Sample ID	Run #	Unit	moisture	Fe	As	Ni	Cu	Zn
9/4/2013	14:22:58	WLP-9a	6	mg/kg-dry	58%	138308	497	259	90	193
9/4/2013	14:23:41	WLP-9a	7	mg/kg-dry	58%	146952	563	158	106	210
9/4/2013	14:24:21	WLP-9a	8	mg/kg-dry	58%	111597	549	137	68	186
9/4/2013	14:24:58	WLP-9a	9	mg/kg-dry	58%	121350	591	87	85	184
9/4/2013	14:25:33	WLP-9a	10	mg/kg-dry	58%	120639	553	139	101	181
9/4/2013	14:28:16	WLP-10a	1	mg/kg-dry	50%	88139	373	71	44	163
9/4/2013	14:28:56	WLP-10a	2	mg/kg-dry	50%	108317	442	129	63	194
9/4/2013	14:29:35	WLP-10a	3	mg/kg-dry	50%	102264	418	147	52	186
9/4/2013	14:30:13	WLP-10a	4	mg/kg-dry	50%	116251	470	145	67	194
9/4/2013	14:30:49	WLP-10a	5	mg/kg-dry	50%	115171	454	141	69	186
9/4/2013	14:31:55	WLP-10a	6	mg/kg-dry	50%	151301	533	236	79	234
9/4/2013	14:32:33	WLP-10a	7	mg/kg-dry	50%	130629	523	121	93	222
9/4/2013	14:33:11	WLP-10a	8	mg/kg-dry	50%	151307	573	176	83	232
9/4/2013	14:33:54	WLP-10a	9	mg/kg-dry	50%	147091	583	194	73	248
9/4/2013	14:34:29	WLP-10a	10	mg/kg-dry	50%	135554	533	137	83	212
9/4/2013	14:39:30	WLP-11a	1	mg/kg-dry	39%	109433	386	145	73	175
9/4/2013	14:40:10	WLP-11a	2	mg/kg-dry	39%	97472	351	99	48	152
9/4/2013	14:40:52	WLP-11a	3	mg/kg-dry	39%	69752	285	71	48	124
9/4/2013	14:41:30	WLP-11a	4	mg/kg-dry	39%	103938	368	64	69	163
9/4/2013	14:42:06	WLP-11a	5	mg/kg-dry	39%	82839	312	104	63	143
9/4/2013	14:42:58	WLP-11a	6	mg/kg-dry	39%	106669	381	173	45	168
9/4/2013	14:43:35	WLP-11a	7	mg/kg-dry	39%	114976	381	160	73	170
9/4/2013	14:44:15	WLP-11a	8	mg/kg-dry	39%	118110	392	157	64	188
9/4/2013	14:44:53	WLP-11a	9	mg/kg-dry	39%	97510	333	79	48	155
9/4/2013	14:45:29	WLP-11a	10	mg/kg-dry	39%	120751	396	191	68	185
9/4/2013	14:48:18	WLP-12a	1	mg/kg-dry	51%	105032	460	145	68	178
9/4/2013	14:48:59	WLP-12a	2	mg/kg-dry	51%	98096	413	139	47	158
9/4/2013	14:49:38	WLP-12a	3	mg/kg-dry	51%	106470	462	158	59	168
9/4/2013	14:50:34	WLP-12a	4	mg/kg-dry	51%	116139	501	145	70	182
9/4/2013	14:51:12	WLP-12a	5	mg/kg-dry	51%	106754	460	133	63	166
9/4/2013	14:52:02	WLP-12a	6	mg/kg-dry	51%	137858	546	176	86	211
9/4/2013	14:52:40	WLP-12a	7	mg/kg-dry	51%	134759	552	196	72	203
9/4/2013	14:53:18	WLP-12a	8	mg/kg-dry	51%	121944	513	127	41	182
9/4/2013	14:53:55	WLP-12a	9	mg/kg-dry	51%	139645	567	174	57	207
9/4/2013	14:54:39	WLP-12a	10	mg/kg-dry	51%	112105	511	192	68	180
9/5/2013	9:51:51	WLP-13a	1	mg/kg-dry	51%	119297	389	164	63	256
9/5/2013	9:52:35	WLP-13a	2	mg/kg-dry	49%	105540	324	127	67	210
9/5/2013	9:53:17	WLP-13a	3	mg/kg-dry	49%	96956	324	115	55	217
9/5/2013	9:53:56	WLP-13a	4	mg/kg-dry	49%	119059	382	188	93	251
9/5/2013	9:54:32	WLP-13a	5	mg/kg-dry	49%	99647	322	152	77	214
9/5/2013	9:55:46	WLP-13a	6	mg/kg-dry	49%	120572	389	117	103	245
9/5/2013	9:56:24	WLP-13a	7	mg/kg-dry	49%	141883	449	144	79	273
9/5/2013	9:57:03	WLP-13a	8	mg/kg-dry	49%	131702	435	166	65	257
9/5/2013	9:57:45	WLP-13a	9	mg/kg-dry	49%	130284	429	210	75	231

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Date	Time	Sample ID	Run #	Unit	moisture	Fe	As	Ni	Cu	Zn
9/5/2013	9:58:20	WLP-13a	10	mg/kg-dry	49%	129915	437	142	75	249
9/5/2013	10:00:59	WLP-14a	1	mg/kg-dry	49%	123945	470	169	74	235
9/5/2013	10:01:37	WLP-14a	2	mg/kg-dry	49%	100409	421	94	49	212
9/5/2013	10:02:17	WLP-14a	3	mg/kg-dry	49%	116998	468	147	63	239
9/5/2013	10:02:55	WLP-14a	4	mg/kg-dry	49%	113819	474	169	74	233
9/5/2013	10:03:31	WLP-14a	5	mg/kg-dry	49%	98455	406	149	49	198
9/5/2013	10:04:20	WLP-14a	6	mg/kg-dry	49%	140728	555	188	82	267
9/5/2013	10:05:01	WLP-14a	7	mg/kg-dry	49%	135077	492	180	74	243
9/5/2013	10:05:40	WLP-14a	8	mg/kg-dry	49%	145606	553	186	76	286
9/5/2013	10:06:18	WLP-14a	9	mg/kg-dry	49%	145367	578	208	102	272
9/5/2013	10:06:52	WLP-14a	10	mg/kg-dry	49%	140203	547	180	84	269
9/5/2013	10:11:43	WLP-15a	1	mg/kg-dry	56%	129647	305	250	57	213
9/5/2013	10:12:24	WLP-15a	2	mg/kg-dry	56%	151090	373	238	82	256
9/5/2013	10:13:03	WLP-15a	3	mg/kg-dry	56%	130199	288	243	78	236
9/5/2013	10:13:43	WLP-15a	4	mg/kg-dry	56%	122087	291	190	76	222
9/5/2013	10:14:20	WLP-15a	5	mg/kg-dry	56%	98918	252	174	66	172
9/5/2013	10:15:19	WLP-15a	6	mg/kg-dry	56%	162304	378	266	92	277
9/5/2013	10:15:57	WLP-15a	7	mg/kg-dry	56%	149359	330	227	98	261
9/5/2013	10:16:38	WLP-15a	8	mg/kg-dry	56%	154357	387	279	71	245
9/5/2013	10:17:21	WLP-15a	9	mg/kg-dry	56%	147337	348	277	80	266
9/5/2013	10:17:58	WLP-15a	10	mg/kg-dry	56%	141189	330	270	94	261
9/5/2013	10:21:33	WLP-16a	1	mg/kg-dry	61%	120083	390	169	80	197
9/5/2013	10:22:12	WLP-16a	2	mg/kg-dry	61%	133250	392	180	64	221
9/5/2013	10:22:50	WLP-16a	3	mg/kg-dry	61%	127631	390	231	59	205
9/5/2013	10:24:05	WLP-16a	4	mg/kg-dry	61%	118363	377	133	74	187
9/5/2013	10:25:03	WLP-16a	5	mg/kg-dry	61%	181504	572	321	113	287
9/5/2013	10:25:42	WLP-16a	6	mg/kg-dry	61%	172094	721	210	62	208
9/5/2013	10:26:20	WLP-16a	7	mg/kg-dry	61%	184568	562	246	90	259
9/5/2013	10:26:58	WLP-16a	8	mg/kg-dry	61%	182788	546	333	108	256
9/5/2013	10:27:35	WLP-16a	9	mg/kg-dry	61%	165850	546	241	85	236
9/9/2013	12:31:13	WLP-16	10	mg/kg-dry	61%	151099	482	144	108	228
9/5/2013	10:38:48	WLP-17a	1	mg/kg-dry	49%	115199	168	156	53	209
9/5/2013	10:39:30	WLP-17a	2	mg/kg-dry	49%	117231	190	120	47	209
9/5/2013	10:40:10	WLP-17a	3	mg/kg-dry	49%	115450	174	150	65	197
9/5/2013	10:40:51	WLP-17a	4	mg/kg-dry	49%	108286	178	154	99	195
9/5/2013	10:41:26	WLP-17a	5	mg/kg-dry	49%	104708	176	134	61	195
9/5/2013	10:42:24	WLP-17a	6	mg/kg-dry	49%	123216	186	138	65	219
9/5/2013	10:43:06	WLP-17a	7	mg/kg-dry	49%	131816	201	148	61	213
9/5/2013	10:43:45	WLP-17a	8	mg/kg-dry	49%	140474	205	255	71	235
9/5/2013	10:44:28	WLP-17a	9	mg/kg-dry	49%	133362	209	160	43	209
9/5/2013	10:45:03	WLP-17a	10	mg/kg-dry	49%	122738	194	144	69	195
9/5/2013	10:47:43	WLP-18a	1	mg/kg-dry	52%	87622	158	145	58	171
9/5/2013	10:48:36	WLP-18a	2	mg/kg-dry	52%	96555	175	157	64	186
9/5/2013	10:49:18	WLP-18a	3	mg/kg-dry	52%	115165	213	171	72	219

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Date	Time	Sample ID	Run #	Unit	moisture	Fe	As	Ni	Cu	Zn
9/5/2013	10:49:55	WLP-18a	4	mg/kg-dry	52%	90973	188	124	47	188
9/5/2013	10:50:30	WLP-18a	5	mg/kg-dry	52%	116467	229	215	70	221
9/5/2013	10:51:30	WLP-18a	6	mg/kg-dry	52%	133085	239	159	60	206
9/5/2013	10:52:11	WLP-18a	7	mg/kg-dry	52%	132065	242	231	97	256
9/5/2013	10:52:50	WLP-18a	8	mg/kg-dry	52%	138386	266	237	60	244
9/5/2013	10:53:36	WLP-18a	9	mg/kg-dry	52%	139557	258	196	97	231
9/5/2013	10:54:13	WLP-18a	10	mg/kg-dry	52%	133521	258	260	99	248
9/5/2013	11:00:01	WLP-19a	1	mg/kg-dry	46%	114168	183	96	81	276
9/5/2013	11:00:41	WLP-19a	2	mg/kg-dry	46%	117902	183	87	81	287
9/5/2013	11:01:00	WLP-19a	3	mg/kg-dry	46%	122604	222	<20	<20	340
9/5/2013	11:02:16	WLP-19a	3	mg/kg-dry	46%	124325	181	59	104	276
9/5/2013	11:02:59	WLP-19a	4	mg/kg-dry	46%	113705	183	94	65	274
9/5/2013	11:04:07	WLP-19a	5	mg/kg-dry	46%	116353	187	135	91	276
9/5/2013	11:04:59	WLP-19a	6	mg/kg-dry	46%	124116	185	93	78	294
9/5/2013	11:05:40	WLP-19a	7	mg/kg-dry	46%	148317	211	150	67	344
9/5/2013	11:07:33	WLP-19a	8	mg/kg-dry	46%	142442	202	170	111	303
9/5/2013	11:08:34	WLP-19a	9	mg/kg-dry	46%	142786	207	146	96	316
9/5/2013	11:09:11	WLP-19a	10	mg/kg-dry	46%	134355	191	131	98	302
9/5/2013	11:11:49	WLP-20a	1	mg/kg-dry	29%	113240	208	123	50	249
9/5/2013	11:13:46	WLP-20a	2	mg/kg-dry	29%	106838	202	94	84	250
9/5/2013	11:14:42	WLP-20a	3	mg/kg-dry	29%	103097	200	112	66	249
9/5/2013	11:15:30	WLP-20a	4	mg/kg-dry	29%	108813	208	83	83	253
9/5/2013	11:16:09	WLP-20a	5	mg/kg-dry	29%	116411	218	101	71	281
9/5/2013	11:17:26	WLP-20a	6	mg/kg-dry	29%	121583	186	126	91	250
9/5/2013	11:18:02	WLP-20a	7	mg/kg-dry	29%	119495	210	76	137	266
9/5/2013	11:18:36	WLP-20a	8	mg/kg-dry	29%	126115	204	119	112	264
9/5/2013	11:19:12	WLP-20a	9	mg/kg-dry	29%	121194	204	147	90	276
9/5/2013	11:19:46	WLP-20a	10	mg/kg-dry	29%	132726	189	99	87	269
9/5/2013	11:46:04	WLP-21a	1	mg/kg-dry	49%	97703	296	80	55	220
9/5/2013	11:47:05	WLP-21a	2	mg/kg-dry	49%	81473	314	<20	57	218
9/5/2013	11:47:42	WLP-21a	3	mg/kg-dry	49%	95477	316	101	78	236
9/5/2013	11:48:21	WLP-21a	4	mg/kg-dry	49%	117805	384	88	96	246
9/5/2013	11:48:59	WLP-21a	5	mg/kg-dry	49%	96492	371	82	96	252
9/5/2013	11:49:54	WLP-21a	6	mg/kg-dry	49%	109888	335	70	76	244
9/5/2013	11:50:32	WLP-21a	7	mg/kg-dry	49%	118987	398	119	88	306
9/5/2013	11:51:20	WLP-21a	8	mg/kg-dry	49%	104731	296	60	70	228
9/5/2013	11:52:02	WLP-21a	9	mg/kg-dry	49%	128608	396	121	127	300
9/5/2013	11:52:43	WLP-21a	10	mg/kg-dry	49%	113797	371	117	92	279
9/5/2013	11:55:50	WLP-22a	1	mg/kg-dry	60%	139730	276	98	75	334
9/5/2013	11:56:33	WLP-22a	2	mg/kg-dry	60%	130755	259	133	90	357
9/5/2013	11:57:13	WLP-22a	3	mg/kg-dry	60%	111139	236	68	90	299
9/5/2013	11:58:01	WLP-22a	4	mg/kg-dry	60%	108379	241	60	93	304
9/5/2013	11:58:39	WLP-22a	5	mg/kg-dry	60%	120275	249	151	95	337
9/5/2013	11:59:32	WLP-22a	6	mg/kg-dry	60%	139740	291	141	108	337

Client: DOH HEER

Project: **Waialoa Arsenic Heterogeneity Study**

GTH ID: HR13-0090Ar1

Date	Time	Sample ID	Run #	Unit	moisture	Fe	As	Ni	Cu	Zn
9/5/2013	12:00:12	WLP-22a	7	mg/kg-dry	60%	166951	299	219	138	377
9/5/2013	12:00:54	WLP-22a	8	mg/kg-dry	60%	159915	317	128	116	379
9/5/2013	12:01:32	WLP-22a	9	mg/kg-dry	60%	126153	284	98	111	327
9/5/2013	12:02:20	WLP-22a	10	mg/kg-dry	60%	168109	319	171	121	369
9/5/2013	12:08:16	WLP-23a	1	mg/kg-dry	50%	118750	291	159	72	223
9/5/2013	12:09:12	WLP-23a	2	mg/kg-dry	50%	96732	241	76	62	197
9/5/2013	12:09:51	WLP-23a	3	mg/kg-dry	50%	108126	257	145	48	217
9/5/2013	12:10:28	WLP-23a	4	mg/kg-dry	50%	115403	281	151	78	229
9/5/2013	12:11:04	WLP-23a	5	mg/kg-dry	50%	108674	265	155	68	209
9/5/2013	12:11:55	WLP-23a	6	mg/kg-dry	50%	129342	306	113	74	231
9/5/2013	12:12:34	WLP-23a	7	mg/kg-dry	50%	129629	314	169	80	245
9/5/2013	12:14:10	WLP-23a	8	mg/kg-dry	50%	134912	291	147	68	243
9/5/2013	12:14:52	WLP-23a	9	mg/kg-dry	50%	130068	298	165	58	221
9/5/2013	12:15:27	WLP-23a	10	mg/kg-dry	50%	124059	293	99	68	243
9/5/2013	12:18:22	WLP-24a	1	mg/kg-dry	39%	99726	180	121	46	168
9/5/2013	12:18:58	WLP-24a	2	mg/kg-dry	39%	69502	144	<20	43	145
9/5/2013	12:19:37	WLP-24a	3	mg/kg-dry	39%	91736	177	102	43	162
9/5/2013	12:20:15	WLP-24a	4	mg/kg-dry	39%	110671	210	159	54	180
9/5/2013	12:20:52	WLP-24a	5	mg/kg-dry	39%	105898	195	127	51	183
9/5/2013	12:22:24	WLP-24a	6	mg/kg-dry	39%	80134	155	119	45	150
9/5/2013	12:23:14	WLP-24a	7	mg/kg-dry	39%	123151	229	152	76	210
9/5/2013	12:23:55	WLP-24a	8	mg/kg-dry	39%	116527	208	147	69	192
9/5/2013	12:25:39	WLP-24a	9	mg/kg-dry	39%	121335	221	152	58	201
9/5/2013	12:26:12	WLP-24a	10	mg/kg-dry	39%	124193	239	121	63	211

Client: DOH HEER

Project: **Waialoa Arsenic Heterogeneity Study**

GTH ID: HR13-0090Ar1

QA/QC

Date	Time	Field Label 1	Unit	Fe	As	Ni	Cu	Zn
9/3/2013	15:38:16	Cal	%					
		NIST						
9/3/2013	15:50:25	SRM2711a	PPM	23737	103	ND	122	348
9/3/2013	15:52:22	Silicon blank	PPM	ND	ND	ND	ND	ND
9/3/2013	15:53:01	Silicon blank	PPM	20	ND	ND	ND	ND
		Hilo ms						
9/3/2013	15:54:46	667ppm	PPM	110874	750	ND	67	229
		Hilo ms						
9/3/2013	15:55:24	667ppm	PPM	117798	635	50	68	225
9/3/2013	15:59:46	Cal	%					
		Hilo ms						
9/3/2013	16:38:51	667ppm	PPM	112843	634	46	61	228
		Hilo ms						
9/3/2013	16:39:58	667ppm	PPM	48016	223	37	29	93
		Hilo ms						
9/3/2013	16:41:03	667ppm	PPM	ND	ND	ND	ND	ND
9/3/2013	16:59:43	Cal	PPM	ND	ND	ND	ND	ND
		NIST						
9/3/2013	17:00:29	SRM2711a	PPM	23549	104	ND	127	350
9/4/2013	13:27:30	Cal	%					
		NIST						
9/4/2013	13:28:51	SRM2711a	PPM	23491	90	ND	129	358
		Hilo ms						
9/4/2013	13:30:38	667ppm	PPM	113675	658	ND	62	220
9/4/2013	13:31:37	Silicon blank	PPM	16	ND	ND	ND	ND
		Hilo ms						
9/4/2013	13:52:57	667ppm	PPM	115805	619	86	62	235
9/4/2013	13:54:03	Silicon blank	PPM	ND	ND	ND	ND	ND
		Hilo ms						
9/4/2013	14:17:00	667ppm	PPM	109842	688	ND	60	229
		Hilo ms						
9/4/2013	14:17:41	667ppm	PPM	ND	ND	ND	ND	ND
		Hilo ms						
9/4/2013	14:37:06	667ppm	PPM	113473	574	ND	61	217
9/4/2013	14:38:15	Silicon blank	PPM	21	ND	ND	ND	ND
		Hilo ms						
9/4/2013	14:58:15	667ppm	PPM	110282	569	80	61	209
		NIST						
9/4/2013	14:59:19	SRM2711a	PPM	24092	85	ND	126	356
		NIST						
9/4/2013	15:00:15	SRM2711a	PPM	23506	106	ND	123	356
9/4/2013	15:01:05	Silicon blank	PPM	26	ND	ND	ND	ND
9/5/2013	9:43:46	Cal	%					
		NIST						
9/5/2013	9:44:59	SRM2711a	PPM	23497	105	ND	123	349

Client: DOH HEER

Project: **Waialoa Arsenic Heterogeneity Study**

GTH ID: HR13-0090Ar1

		Hilo ms						
9/5/2013	9:45:58	667ppm	PPM	114335	565	79	63	212
9/5/2013	9:46:58	Silicon blank	PPM	27	ND	ND	ND	ND
		Hilo ms						
9/5/2013	10:09:34	667ppm	PPM	114823	611	44	72	215
9/5/2013	10:10:30	Silicon blank	PPM	30	ND	ND	ND	ND
		Hilo ms						
9/5/2013	10:30:21	667ppm	PPM	112160	663	62	70	223
9/5/2013	10:31:19	Silicon blank	PPM	37	ND	ND	ND	ND
		Hilo ms						
9/5/2013	10:57:33	667ppm	PPM	108621	586	ND	60	219
9/5/2013	10:58:26	Silicon blank	PPM	24	ND	ND	ND	ND
		Hilo ms						
9/5/2013	11:22:48	667ppm	PPM	114548	635	50	57	217
9/5/2013	11:23:55	Silicon blank	PPM	42	ND	ND	ND	ND
		Hilo ms						
9/5/2013	12:06:03	667ppm	PPM	114127	597	67	59	214
9/5/2013	12:07:03	Silicon blank	PPM	34	ND	ND	ND	ND
		Hilo ms						
9/5/2013	12:28:47	667ppm	PPM	116971	652	61	61	224
		NIST						
9/5/2013	12:29:40	SRM2711a	PPM	23681	91	ND	129	364
9/5/2013	12:30:33	Silicon blank	PPM	30	ND	ND	ND	ND
		WLP-24 inst						
9/5/2013	12:32:20	dri	PPM	62342	113	91	31	119
		WLP-24 inst						
9/5/2013	12:32:54	dri	PPM	62333	114	80	35	121
		WLP-24 inst						
9/5/2013	12:33:30	dri	PPM	61957	117	53	35	120
		WLP-24 inst						
9/5/2013	12:34:04	dri	PPM	62224	112	62	39	112
		WLP-24 inst						
9/5/2013	12:34:41	dri	PPM	61385	120	70	39	117
		WLP-24 inst						
9/5/2013	12:35:16	dri	PPM	62710	116	74	38	118
		WLP-24 inst						
9/5/2013	12:35:49	dri	PPM	61758	121	83	34	116
		Hilo ms						
9/5/2013	12:37:02	667ppm	PPM	111416	735	ND	65	227
		NIST						
9/5/2013	12:37:57	SRM2711a	PPM	23994	105	ND	126	369
9/5/2013	12:38:49	Silicon blank	PPM	21	ND	ND	ND	ND
		NIST						
9/9/2013	12:18:57	SRM2711a	PPM	23584	95	ND	125	349
		Hilo ms						
9/9/2013	12:20:02	667ppm	PPM	116832	733	50	79	239
9/9/2013	12:25:33	Silicon blank	PPM	32	ND	ND	ND	ND

Client: DOH HEER

Project: **Waialoa Arsenic Heterogeneity Study**

GTH ID: HR13-0090Ar1

SRM Recovery

Date	Time	Field Label 1	NIST Actual Values				
			Fe	As	Ni	Cu	Zn
			28200	107	21.7	140	414
9/3/2013	15:38:16	Cal	Recoveries				
9/3/2013	15:50:25	NIST SRM2711a	84%	96%	NA	87%	84%
9/3/2013	17:00:29	NIST SRM2711a	84%	97%	NA	91%	85%
9/4/2013	13:28:51	NIST SRM2711a	83%	84%	NA	92%	86%
9/4/2013	14:59:19	NIST SRM2711a	85%	79%	NA	90%	86%
9/4/2013	15:00:15	NIST SRM2711a	83%	99%	NA	88%	86%
9/5/2013	9:44:59	NIST SRM2711a	83%	98%	NA	88%	84%
9/5/2013	12:29:40	NIST SRM2711a	84%	85%	NA	92%	88%
9/5/2013	12:37:57	NIST SRM2711a	85%	98%	NA	90%	89%
9/9/2013	12:18:57	NIST SRM2711a	84%	89%	NA	89%	84%

Matrix Spike Recovery

Date	Time	Field Label 1	Hilo As
			MS value
			As Actual
			667
9/3/2013	15:54:46	Hilo ms 667ppm	112%
9/3/2013	15:55:24	Hilo ms 667ppm	95%
9/3/2013	16:38:51	Hilo ms 667ppm	95%
9/4/2013	13:30:38	Hilo ms 667ppm	99%
9/4/2013	13:52:57	Hilo ms 667ppm	93%
9/4/2013	14:17:00	Hilo ms 667ppm	103%
9/4/2013	14:37:06	Hilo ms 667ppm	86%
9/4/2013	14:58:15	Hilo ms 667ppm	85%
9/5/2013	9:45:58	Hilo ms 667ppm	85%
9/5/2013	10:09:34	Hilo ms 667ppm	92%
9/5/2013	10:30:21	Hilo ms 667ppm	99%
9/5/2013	10:57:33	Hilo ms 667ppm	88%
9/5/2013	11:22:48	Hilo ms 667ppm	95%
9/5/2013	12:06:03	Hilo ms 667ppm	90%
9/5/2013	12:28:47	Hilo ms 667ppm	98%
9/5/2013	12:37:02	Hilo ms 667ppm	110%
9/9/2013	12:20:02	Hilo ms 667ppm	110%

Client: DOH HEER

Project: **Waialoa Arsenic Heterogeneity Study**

GTH ID: HR13-0090Ar1

Replicate Data

			replicate RSD					
			Fe	As	Ni	Cu	Zn	
9/5/2013	12:32:20	WLP-24 inst dri	Average	62101.29	116.1429	73.28571	35.85714	117.5714
9/5/2013	12:32:54	WLP-24 inst dri	STDEV	437.5986	3.436499	12.93206	2.968084	2.992053
9/5/2013	12:33:30	WLP-24 inst dri	RSD	0.7%	3.0%	17.6%	8.3%	2.5%
9/5/2013	12:34:04	WLP-24 inst dri						
9/5/2013	12:34:41	WLP-24 inst dri						
9/5/2013	12:35:16	WLP-24 inst dri						
9/5/2013	12:35:49	WLP-24 inst dri						

Client: HDOH HEER
Project: Waialoa Arsenic Heterogeneity Study
GeoTek Hawaii Project#: HR13-0090Ar1

Appendix

Figure 1 reference Spectra of CANEC taken from camp 2



Figure 2 reference spectra for arsenic contaminated soil taken from camp 2



Figure 3. Reference spectra of a background soil sample taken from Camp 2.



Figure 4. Sampling grid and sample being prepared for analysis.



Figure 5. Taking an XRF reading of a sample.



>>> Select a Laboratory <<<

Chain of Custody Record

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Laboratories, Inc.

#N/A
#N/A
#N/A

Regulatory Program: DW NPDES RCRA Other:

Project Manager: Roger Brewer

Site Contact: Roger Brewer

Date: Aug 26, 2013

COC No:

1 of 2 COCs

Sampler: Roger Brewer

For Lab Use Only:

Walk-in Client:

Lab Sampling:

Job / SDG No.:

MW10022

Sample Specific Notes:

MW10022-01

-02

-03

-04

-05

-06

-07

-08

-09

-10

-11

-12

Lab Contact:

Grain Size (ASTM D-422/421)

Total Arsenic (6010B) (Y/N)

Perform MS/MSD (Y/N)

Filtered Sample (Y/N)

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

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X

X

X

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TellFax: 1-808-586-4249

Analysis Turnaround Time

CALENDAR DAYS WORKING DAYS

TAT if different from Below

2 weeks

1 week

2 days

1 day

Client Contact

Hawaii Dept. of Health, HEER

919 Ala Moana Blvd, Room 206

Honolulu, HI 96814

Phone: (808) 586-4249

Fax: (808) 586-7537

Project Name: Waialoa Park Arsenic Study

Site: Waialoa Park, Hilo

P O # 1097589

Sample Date

Sample Time

Sample Type (C=Comp, G=Grab)

Matrix

of Cont.

8/22/2013

2:30pm

G

Soil

1

8/22/2013

2:30pm

Sample Identification

WLP-1A

WLP-2A

WLP-3A

WLP-4A

WLP-5A

WLP-6A

WLP-7A

WLP-8A

WLP-9A

WLP-10A

WLP-11A

WLP-12A

WLP-13A

WLP-14A

WLP-15A

WLP-16A

WLP-17A

WLP-18A

WLP-19A

WLP-20A

WLP-21A

WLP-22A

WLP-23A

WLP-24A

WLP-25A

WLP-26A

WLP-27A

WLP-28A

WLP-29A

WLP-30A

WLP-31A

WLP-32A

WLP-33A

WLP-34A

WLP-35A

WLP-36A

WLP-37A

WLP-38A

WLP-39A

WLP-40A

WLP-41A

WLP-42A

WLP-43A

WLP-44A

WLP-45A

WLP-46A

WLP-47A

WLP-48A

WLP-49A

WLP-50A

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)

Return to Client

Disposal by Lab

Archive for

Months

Return to Client

Disposal by Lab

Archive for

Months

Return to Client

Disposal by Lab

Archive for

Months

Return to Client

Disposal by Lab

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Return to Client

Disposal by Lab

Archive for

Months

Return to Client

Disposal by Lab

Archive for

Months

Return to Client

Disposal by Lab

Archive for

Company: HDOH

Date/Time: 8/26/13 12:39

Company: Grace Lee Hawaii

Date/Time: 8/26/13 12:39

Company: T.A.L.

Date/Time: 9/5/13 15:00

Special Instructions/QC Requirements & Comments:

*Process samples using Multi-Increment Sample SOP (e.g., air dry entire sample, sieve to <2mm, collect 30 subsamples per aliquot to be tested, minimum ten-gram aliquots extracted for total metals).

Custody Seal No.:

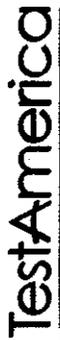
Relinquished by: [Signature]

Relinquished by: [Signature]

>>> Select a Laboratory <<<

#N/A
#N/A
#N/A
#N/A

Chain of Custody Record



THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Laboratories, Inc.

Client Contact
 Hawaii Dept. of Health, HEER
 919 Ala Moana Blvd, Room 206
 Honolulu, HI 96814
 Phone: (808) 586-4249
 Fax: (808) 586-7537
 Project Name: Waiioa Park Arsenic Study
 Site: Waiioa Park, Hilo
 P O # 1097584

Regulatory Program: DW NPDES RCRA Other: _____
Project Manager: Roger Brewer
Tel/Fax: 1-808-586-4249

Analysis Turnaround Time
 CALENDAR DAYS WORKING DAYS
 TAT if different from Below _____
 2 weeks
 1 week
 2 days
 1 day

Site Contact: Roger Brewer
Date: Aug 26, 2013
Carrier: _____

COC No: _____
1 of 2 COCs

For Lab Use Only:
Sampler: Roger Brewer
Walk-in Client: _____
Lab Sampling: KW10022
Job / SDG No.: _____

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=Grab)	Matrix	# of Cont.	Lab Contact:			Sample Specific Notes:
						Filtered Sample (Y/N)	Perform MS/MSD (Y/N)	Grain Size (ASTM D-422/421)	
WLP-13A	8/22/2013	2:30pm	G	Soil	1	X	X	X	KW10022-13
WLP-14A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-14
WLP-15A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-15
WLP-16A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-16
WLP-17A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-17
WLP-18A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-18
WLP-19A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-19
WLP-20A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-20
WLP-21A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-21
WLP-22A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-22
WLP-23A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-23
WLP-24A	8/22/2013	2:30pm	G	Soil	1	X	X	X	-24

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
 Return to Client Disposal by Lab Archive for _____ Months

Special Instructions/QC Requirements & Comments:
 Process samples using Multi-Increment Sample SOP (e.g., air dry entire sample, sieve to <2mm, collect 30 subsamples per aliquot to be tested, minimum ten-gram aliquots extracted for total metals).

Relinquished by: _____
Relinquished by: _____
Relinquished by: _____

Custody Seal No.: _____
Company: HDOH
Company: GeoTel Hawaii
Company: _____

Date/Time: 8/26/13 12:38
Date/Time: 9/5/13 15:00
Date/Time: _____

Received by: _____
Received by: _____
Received in Laboratory by: _____

Cooler Temp. (°C): Obs'd: _____ Cor'd: _____
Therm ID No.: _____

Waipahu Incinerator XRF Readings (Grid Points 1-6)

Date	Time	Field Label 1	Field 1	Reading	Unit	Cu	Fe	Pb	Ni	Zn
3/11/2014	14:54:00	Cal	Pb val	#1	%					
3/11/2014	14:58:57	NIST2711A	1400	#2	PPM	126	23,452	1,377	ND	359
3/11/2014	15:00:18	WIFS0310	1621	#3	PPM	169	102,365	1,551	162	1,290
3/11/2014	15:02:44	SiO2 Blk	0	#4	PPM	ND	52	ND	ND	ND
3/11/2014	15:12:13	WI-1AA		#5	PPM	155	92,023	232	134	832
3/11/2014	15:13:03	WI-1AB		#6	PPM	162	91,160	222	146	797
3/11/2014	15:13:48	WI-1AC		#7	PPM	157	88,381	219	167	802
3/11/2014	15:15:06	WI-1AD		#8	PPM	167	94,649	244	178	835
3/11/2014	15:15:51	WI-1AE		#9	PPM	165	88,751	359	186	1,094
3/11/2014	15:19:56	WI-1AF		#10	PPM	154	93,134	231	180	810
3/11/2014	15:20:30	WI-1AG		#11	PPM	173	110,286	355	223	960
3/11/2014	15:21:04	WI-1AH		#12	PPM	209	108,700	176	267	679
3/11/2014	15:21:38	WI-1AI		#13	PPM	156	90,756	269	201	861
3/11/2014	15:22:11	WI-1AJ		#14	PPM	173	107,875	224	254	749
3/11/2014	15:24:58	WI-2AA		#15	PPM	183	123,343	276	207	795
3/11/2014	15:25:44	WI-2AB		#16	PPM	202	94,146	270	178	866
3/11/2014	15:26:26	WI-2AC		#17	PPM	135	111,300	89	237	358
3/11/2014	15:27:16	WI-2AD		#18	PPM	149	136,006	19	213	201
3/11/2014	15:28:01	WI-2AE		#19	PPM	174	139,322	40	226	242
3/11/2014	15:29:05	WI-2AF		#20	PPM	156	113,226	67	287	268
3/11/2014	15:29:40	WI-2AG		#21	PPM	143	104,601	87	230	359
3/11/2014	15:30:16	WI-2AH		#22	PPM	166	108,504	101	325	407
3/11/2014	15:30:50	WI-2AI		#23	PPM	129	106,446	32	206	198
3/11/2014	15:31:24	WI-2AJ		#24	PPM	168	128,091	64	285	326
3/11/2014	15:37:05	NIST2711A	1400	#25	PPM	129	23,600	1,383	ND	353
3/11/2014	15:37:56	WIFS0310	1621	#26	PPM	189	100,378	1,622	115	1,283
3/11/2014	15:38:57	SiO2 Blk	0	#27	PPM	ND	57	ND	ND	ND

Waipahu Incinerator XRF Readings (Grid Points 1-6)

Date	Time	Field Label 1	Field 1	Reading	Unit	Cu	Fe	Pb	Ni	Zn
3/11/2014	15:40:49	WI-3AA		#28	PPM	157	75,131	366	49	932
3/11/2014	15:41:31	WI-3AB		#29	PPM	197	74,862	349	ND	1,056
3/11/2014	15:42:09	WI-3AC		#30	PPM	195	90,430	261	ND	1,354
3/11/2014	15:42:48	WI-3AD		#31	PPM	150	71,112	235	67	782
3/11/2014	15:43:25	WI-3AE		#32	PPM	176	75,912	317	60	881
3/11/2014	15:44:01	WI-3AF		#33	PPM	241	69,803	286	40	843
3/11/2014	15:45:24	WI-3AG		#34	PPM	168	77,275	252	69	822
3/11/2014	15:46:08	WI-3AH		#35	PPM	192	84,426	320	133	959
3/11/2014	15:46:46	WI-3AI		#36	PPM	209	139,684	98	209	441
3/11/2014	15:47:25	WI-3AJ		#37	PPM	188	102,091	212	217	828
3/11/2014	15:59:35	WI-4AA		#38	PPM	279	90,064	585	58	1,892
3/11/2014	16:00:30	WI-4AB		#39	PPM	206	102,697	462	42	1,341
3/11/2014	16:01:28	WI-4AC		#40	PPM	153	90,783	283	ND	1,037
3/11/2014	16:02:09	WI-4AD		#41	PPM	165	85,205	334	ND	1,063
3/11/2014	16:03:04	WI-4AE		#42	PPM	317	81,703	643	53	2,121
3/11/2014	16:03:57	WI-4AF		#43	PPM	266	82,192	812	46	1,801
3/11/2014	16:14:51	WI-4AG		#44	PPM	279	100,561	1,014	68	2,472
3/11/2014	16:16:34	WI-4AH		#45	PPM	249	69,710	799	50	1,832
3/11/2014	16:17:18	WI-4AI		#46	PPM	232	120,378	556	44	1,637
3/11/2014	16:18:50	WI-4AJ		#47	PPM	246	71,653	703	60	1,854
3/11/2014	16:41:53	NIST2711A	1400	#48	PPM	122	23,703	1,382	ND	355
3/11/2014	16:44:41	WIFS0310	1621	#49	PPM	197	93,371	1,710	168	1,277
3/11/2014	16:46:09	SiO2 Blk	0	#50	PPM	ND	32	ND	ND	ND
3/11/2014	16:49:07	WI-5AA		#51	PPM	162	115,674	67	309	308
3/11/2014	16:50:47	WI-5AB		#52	PPM	188	137,831	56	328	349
3/11/2014	16:51:28	WI-5AC		#53	PPM	119	70,607	139	144	537
3/11/2014	16:52:07	WI-5AD		#54	PPM	150	69,400	188	141	624

Waipahu Incinerator XRF Readings (Grid Points 1-6)

Date	Time	Field Label 1	Field 1	Reading	Unit	Cu	Fe	Pb	Ni	Zn
3/11/2014	16:52:46	WI-5AE		#55	PPM	144	99,086	152	243	501
3/11/2014	16:54:11	WI-5AF		#56	PPM	188	129,433	168	319	575
3/11/2014	16:54:53	WI-5AG		#57	PPM	195	129,745	140	414	530
3/11/2014	16:55:36	WI-5AH		#58	PPM	193	134,203	60	333	363
3/11/2014	16:56:43	WI-5AI		#59	PPM	179	128,835	173	420	617
3/11/2014	16:57:22	WI-5AJ		#60	PPM	197	148,358	63	294	381
3/11/2014	17:03:45	WI-6AA		#61	PPM	147	109,113	55	323	273
3/11/2014	17:04:29	WI-6AB		#62	PPM	183	129,334	41	352	254
3/11/2014	17:05:05	WI-6AC		#63	PPM	140	66,358	212	155	1,854
3/11/2014	17:07:24	WI-6AD		#64	PPM	127	53,833	185	107	687
3/11/2014	17:08:06	WI-6AE		#65	PPM	158	81,451	327	150	961
3/11/2014	17:10:01	WI-6AF		#66	PPM	183	121,963	372	265	1,014
3/11/2014	17:10:37	WI-6AG		#67	PPM	188	122,465	167	295	514
3/11/2014	17:11:13	WI-6AH		#68	PPM	186	108,282	253	272	814
3/11/2014	17:11:49	WI-6AI		#69	PPM	156	109,753	236	231	862
3/11/2014	17:12:36	WI-6AJ		#70	PPM	173	121,412	84	312	411
3/11/2014	17:21:00	CAL		#71	%					
3/11/2014	17:39:27	CAL		#72	%					
3/11/2014	17:40:26	CAL		#73	%					
3/11/2014	17:41:21	NIST2711A	1400	#74	PPM	123	23,514	1,388	ND	361
3/11/2014	17:42:34	WIFS0310	1621	#75	PPM	192	96,587	1,665	149	1,237
3/11/2014	17:43:26	SiO2 Blk	0	#76	PPM	ND	55	ND	ND	ND

Waipahu Incinerator XRF Readings (Grid Points 7-14)

Date	Time	Field Label 1	Reading	Unit	Elapsed						
					Time Total	As	Cu	Fe	Pb	Ni	Zn
3/13/2014	10:34:42	Cal	#1	%	14.89						
3/13/2014	14:28:01	SRM2711	#2	PPM	28.68	97	124	23761	1394	ND	354
3/13/2014	14:29:27	WIFS0310	#3	PPM	28.64	77	202	98611	1613	135	1320
3/13/2014	14:30:40	SiO2 Blank	#4	PPM	28.61	ND	ND	41	ND	ND	ND
3/13/2014	14:43:51	WI-7AA	#5	PPM	29.05	36	148	90405	327	172	854
3/13/2014	14:44:41	WI-7AB	#6	PPM	28.84	28	160	103186	295	187	843
3/13/2014	14:51:06	WI-7AC	#7	PPM	29.01	29	156	111863	191	243	489
3/13/2014	14:51:46	WI-7AD	#8	PPM	29.03	28	171	98141	337	132	1017
3/13/2014	14:52:21	WI-7AE	#9	PPM	29.1	19	133	90689	166	172	604
3/13/2014	14:53:50	WI-7AF	#10	PPM	28.91	36	161	107830	270	220	883
3/13/2014	14:54:25	WI-7AG	#11	PPM	28.93	35	152	105108	222	214	712
3/13/2014	14:55:01	WI-7AH	#12	PPM	28.92	34	165	103628	216	192	733
3/13/2014	14:55:38	WI-7AI	#13	PPM	28.74	35	184	108606	311	256	883
3/13/2014	14:56:15	WI-7AJ	#14	PPM	28.84	35	168	100305	214	192	696
3/13/2014	14:59:10	WI-8AA	#15	PPM	29.06	16	191	87651	361	76	1013
3/13/2014	14:59:57	WI-8AB	#16	PPM	28.92	27	222	101158	396	119	1123
3/13/2014	15:00:39	WI-8AC	#17	PPM	28.96	21	162	77845	259	78	818
3/13/2014	15:01:15	WI-8AD	#18	PPM	29.25	36	183	84784	338	81	908
3/13/2014	15:01:53	WI-8AE	#19	PPM	29.05	24	156	96663	353	157	812
3/13/2014	15:03:08	WI-8AF	#20	PPM	28.69	29	246	91505	261	167	2564
3/13/2014	15:03:44	WI-8AG	#21	PPM	28.91	32	233	101560	259	224	594
3/13/2014	15:04:21	WI-8AH	#22	PPM	28.82	37	177	89961	170	172	606
3/13/2014	15:05:00	WI-8AI	#23	PPM	28.7	31	182	127739	85	304	359
3/13/2014	15:05:36	WI-8AJ	#24	PPM	28.88	33	153	79496	193	138	628
3/13/2014	15:07:45	SRM2711	#25	PPM	28.68	96	114	23518	1395	ND	353
3/13/2014	15:08:28	WIFS0310	#26	PPM	28.58	41	195	95807	1621	148	1297
3/13/2014	15:09:45	SiO2 Blank	#27	PPM	28.63	ND	ND	31	ND	ND	ND
3/13/2014	15:23:29	WI-9AA	#28	PPM	29.09	39	175	133600	74	346	331
3/13/2014	15:24:16	WI-9AB	#29	PPM	29.07	38	185	136425	94	343	361

Waipahu Incinerator XRF Readings (Grid Points 7-14)

Date	Time	Field Label 1	Reading	Unit	Elapsed Time Total	As	Cu	Fe	Pb	Ni	Zn
3/13/2014	15:24:53	WI-9AC	#30	PPM	29.08	45	167	132520	176	273	563
3/13/2014	15:25:31	WI-9AD	#31	PPM	29.23	40	177	135437	65	415	335
3/13/2014	15:26:07	WI-9AE	#32	PPM	29.09	38	171	128505	101	367	396
3/13/2014	15:27:37	WI-9AF	#33	PPM	28.8	39	186	135386	164	315	522
3/13/2014	15:28:13	WI-9AG	#34	PPM	28.9	42	194	142031	113	330	472
3/13/2014	15:28:49	WI-9AH	#35	PPM	28.79	37	182	134530	38	353	272
3/13/2014	15:29:27	WI-9AI	#36	PPM	28.75	46	207	136568	126	346	457
3/13/2014	15:30:17	WI-9AJ	#37	PPM	28.95	43	183	135338	114	298	453
3/13/2014	15:34:13	WI-10AA	#38	PPM	29.05	30	176	109498	198	252	596
3/13/2014	15:35:00	WI-10AB	#39	PPM	29.17	21	122	92362	131	196	458
3/13/2014	15:35:37	WI-10AC	#40	PPM	29.26	21	111	84787	88	164	299
3/13/2014	15:36:13	WI-10AD	#41	PPM	29.16	27	110	90280	147	174	473
3/13/2014	15:36:50	WI-10AE	#42	PPM	28.99	33	157	108817	265	229	743
3/13/2014	15:38:50	WI-10AF	#43	PPM	28.83	33	149	109404	223	197	611
3/13/2014	15:39:28	WI-10AG	#44	PPM	28.8	24	136	98484	86	209	310
3/13/2014	15:40:05	WI-10AH	#45	PPM	28.89	27	132	98008	55	183	258
3/13/2014	15:40:43	WI-10AI	#46	PPM	28.79	27	152	102417	85	348	345
3/13/2014	15:41:18	WI-10AJ	#47	PPM	28.8	24	133	86970	62	196	232
3/13/2014	15:43:39	SRM2711	#48	PPM	28.67	95	129	23605	1400	ND	358
3/13/2014	15:44:33	WIFS0310	#49	PPM	28.59	59	191	96976	1646	152	1320
3/13/2014	15:45:22	SiO2 Blank	#50	PPM	28.62	ND	ND	26	ND	ND	ND
3/13/2014	15:46:24	WI-11AA	#51	PPM	28.82	25	173	86263	284	168	794
3/13/2014	15:47:08	WI-11AB	#52	PPM	29.23	ND	82	44810	221	70	557
3/13/2014	15:47:45	WI-11AC	#53	PPM	28.94	11	205	52388	198	70	560
3/13/2014	15:48:48	WI-11AD	#54	PPM	29.02	21	118	62425	168	139	652
3/13/2014	15:49:30	WI-11AE	#55	PPM	29.1	23	129	81452	234	102	781
3/13/2014	15:51:03	WI-11AF	#56	PPM	29.15	33	155	96257	237	200	784
3/13/2014	15:51:41	WI-11AG	#57	PPM	28.77	26	138	96996	253	200	792
3/13/2014	15:52:17	WI-11AH	#58	PPM	28.77	32	159	99269	173	216	620

Waipahu Incinerator XRF Readings (Grid Points 7-14)

Date	Time	Field Label 1	Reading	Unit	Elapsed						
					Time Total	As	Cu	Fe	Pb	Ni	Zn
3/13/2014	15:52:57	WI-11AI	#59	PPM	28.92	32	167	96886	253	183	786
3/13/2014	15:53:36	WI-11AJ	#60	PPM	28.84	31	150	103283	150	222	453
3/13/2014	15:56:07	WI-12AA	#61	PPM	29.1	33	158	85682	444	99	1154
3/13/2014	15:56:47	WI-12AB	#62	PPM	29.03	47	132	91284	343	93	1087
3/13/2014	15:57:31	WI-12AC	#63	PPM	29.03	35	117	65604	263	101	889
3/13/2014	15:58:40	WI-12AD	#64	PPM	28.98	44	170	103189	525	92	1576
3/13/2014	15:59:29	WI-12AE	#65	PPM	28.85	37	226	105941	659	130	1627
3/13/2014	16:00:42	WI-12AF	#66	PPM	28.87	38	146	98090	345	179	869
3/13/2014	16:01:16	WI-12AG	#67	PPM	29.25	32	152	91221	307	170	835
3/13/2014	16:01:54	WI-12AH	#68	PPM	29.07	30	165	87370	501	142	1164
3/13/2014	16:02:33	WI-12AI	#69	PPM	29.14	24	122	85542	250	143	717
3/13/2014	16:03:10	WI-12AJ	#70	PPM	29.11	44	129	88566	378	156	1106
3/13/2014	16:06:01	SRM2711	#71	PPM	28.69	92	129	24010	1402	ND	352
3/13/2014	16:06:52	WIFS0310	#72	PPM	28.63	62	180	95348	1569	140	1314
3/13/2014	16:07:59	SiO2 Blank	#73	PPM	28.62	ND	ND	20	ND	ND	ND
3/13/2014	16:09:17	WI-13AA	#74	PPM	29.04	30	134	109159	285	223	656
3/13/2014	16:10:48	WI-13AB	#75	PPM	29.13	15	135	97565	249	199	777
3/13/2014	16:11:25	WI-13AC	#76	PPM	28.89	28	147	99318	275	189	873
3/13/2014	16:12:29	WI-13AD	#77	PPM	29.12	16	114	68528	197	130	692
3/13/2014	16:13:08	WI-13AE	#78	PPM	29.01	22	146	92541	223	193	868
3/13/2014	16:14:29	WI-13AF	#79	PPM	28.97	27	137	105803	188	203	522
3/13/2014	16:15:06	WI-13AG	#80	PPM	28.79	32	134	109848	173	233	573
3/13/2014	16:15:41	WI-13AH	#81	PPM	29.06	24	133	100053	111	256	404
3/13/2014	16:16:20	WI-13AI	#82	PPM	28.95	34	149	112088	135	238	392
3/13/2014	16:16:58	WI-13AJ	#83	PPM	28.89	32	139	102817	129	210	413
3/13/2014	16:19:39	WI-14AA	#84	PPM	29.16	20	124	79073	234	138	735
3/13/2014	16:20:19	WI-14AB	#85	PPM	28.83	16	108	56724	156	165	600
3/13/2014	16:20:55	WI-14AC	#86	PPM	29.18	15	112	65337	171	87	618
3/13/2014	16:21:37	WI-14AD	#87	PPM	29.02	22	121	80998	195	168	711

Waipahu Incinerator XRF Readings (Grid Points 7-14)

Date	Time	Field Label 1	Reading	Unit	Elapsed Time Total	As	Cu	Fe	Pb	Ni	Zn
3/13/2014	16:22:15	WI-14AE	#88	PPM	28.9	17	138	79807	221	124	714
3/13/2014	16:22:49	WI-14AF	#89	PPM	28.98	17	132	72901	207	120	662
3/13/2014	16:24:08	WI-14AG	#90	PPM	28.96	36	158	124440	69	263	294
3/13/2014	16:24:42	WI-14AH	#91	PPM	28.98	32	140	110260	85	207	312
3/13/2014	16:25:23	WI-14AI	#92	PPM	28.91	29	152	101724	225	207	667
3/13/2014	16:25:56	WI-14AJ	#93	PPM	28.95	30	176	95232	118	202	384
3/13/2014	16:28:20	SRM2711	#94	PPM	28.71	101	121	24200	1403	ND	371
3/13/2014	16:29:18	WIFS0310	#95	PPM	28.59	72	197	96960	1637	134	1347
3/13/2014	16:30:08	SiO2 Blank	#96	PPM	28.63	ND	ND	22	ND	ND	ND

Waipahu Incinerator XRF Readings (Grid Points 15-24)

Date	Time	Field Label 1	Reading	Unit	Elapsed Time Total	As	Cu	Fe	Pb	Ni	Zn
3/14/2014	11:35:56	Cal	#1	%	14.89						
3/14/2014	11:52:09	NIST2711a	#2	PPM	28.67	108	121	23763	1377	ND	357
3/14/2014	11:53:36	WIFS0310	#3	PPM	28.66	75	190	97339	1640	141	1316
3/14/2014	11:54:29	SiO2 Blank	#4	PPM	28.61	ND	ND	22	ND	ND	ND
3/14/2014	11:55:50	WI-15AA	#5	PPM	28.93	28	135	85026	203	132	786
3/14/2014	11:56:34	WI-15AB	#6	PPM	29.03	15	89	52145	195	138	701
3/14/2014	11:57:09	WI-15AC	#7	PPM	28.99	32	139	83674	367	131	1046
3/14/2014	11:57:47	WI-15AD	#8	PPM	29	12	97	41382	208	69	767
3/14/2014	11:58:23	WI-15AE	#9	PPM	28.93	22	119	56772	230	109	819
3/14/2014	11:59:37	WI-15AF	#10	PPM	28.85	29	135	92235	276	157	837
3/14/2014	12:00:16	WI-15AG	#11	PPM	28.77	46	154	106746	145	190	558
3/14/2014	12:00:51	WI-15AH	#12	PPM	28.83	32	138	103934	209	175	628
3/14/2014	12:01:33	WI-15AI	#13	PPM	28.97	34	145	100581	168	183	588
3/14/2014	12:02:11	WI-15AJ	#14	PPM	28.87	32	142	111957	131	204	488
3/14/2014	12:07:10	WI-16AA	#15	PPM	28.82	26	161	91025	457	140	1264
3/14/2014	12:07:55	WI-16AB	#16	PPM	29.13	41	179	117906	308	280	843
3/14/2014	12:08:32	WI-16AC	#17	PPM	28.94	24	146	102253	238	201	623
3/14/2014	12:09:12	WI-16AD	#18	PPM	29.19	28	143	84406	269	208	728
3/14/2014	12:09:46	WI-16AE	#19	PPM	29.11	36	153	99877	289	228	719
3/14/2014	12:11:26	WI-16AF	#20	PPM	28.86	38	171	100895	292	248	723
3/14/2014	12:12:33	WI-16AG	#21	PPM	28.95	38	156	97106	286	429	747
3/14/2014	12:13:11	WI-16AH	#22	PPM	28.8	37	169	102770	412	262	1179
3/14/2014	12:13:46	WI-16AI	#23	PPM	28.83	46	207	109285	305	286	794
3/14/2014	12:14:37	WI-16AJ	#24	PPM	28.96	33	155	92387	324	186	750
3/14/2014	12:16:25	NIST2711a	#25	PPM	28.67	95	124	24197	1411	ND	355
3/14/2014	12:17:23	WIFS0310	#26	PPM	28.59	51	182	97748	1657	155	1337
3/14/2014	12:18:14	SiO2 Blank	#27	PPM	28.6	ND	ND	33	ND	ND	ND
3/14/2014	12:19:26	WI-17AA	#28	PPM	29.01	18	129	66217	243	118	713
3/14/2014	12:20:05	WI-17AB	#29	PPM	29.12	12	78	59638	171	51	461

Waipahu Incinerator XRF Readings (Grid Points 15-24)

Date	Time	Field Label 1	Reading	Unit	Elapsed Time Total	As	Cu	Fe	Pb	Ni	Zn
3/14/2014	12:20:42	WI-17AC	#30	PPM	29.16	12	80	45656	193	94	563
3/14/2014	12:21:20	WI-17AD	#31	PPM	29.12	26	131	78485	185	103	401
3/14/2014	12:21:56	WI-17AE	#32	PPM	29.02	23	133	74895	255	146	663
3/14/2014	12:23:10	WI-17AF	#33	PPM	28.95	31	137	96314	362	137	743
3/14/2014	12:23:45	WI-17AG	#34	PPM	28.77	33	152	96628	305	156	535
3/14/2014	12:24:20	WI-17AH	#35	PPM	28.85	ND	166	97071	677	216	1061
3/14/2014	12:25:12	WI-17AI	#36	PPM	28.92	25	168	87159	299	156	543
3/14/2014	12:25:56	WI-17AJ	#37	PPM	28.96	32	161	99350	422	110	885
3/14/2014	12:30:55	WI-18AA	#38	PPM	28.87	27	123	72104	344	192	754
3/14/2014	12:31:32	WI-18AB	#39	PPM	29.05	23	111	63460	308	109	694
3/14/2014	12:32:09	WI-18AC	#40	PPM	28.93	21	79	46247	123	131	488
3/14/2014	12:34:13	WI-18AD	#41	PPM	29.19	16	98	66112	209	152	423
3/14/2014	12:34:47	WI-18AE	#42	PPM	29	15	103	59036	327	103	649
3/14/2014	12:36:00	WI-18AF	#43	PPM	28.86	30	135	86755	291	217	698
3/14/2014	12:36:40	WI-18AG	#44	PPM	28.85	45	161	93170	504	231	868
3/14/2014	12:37:16	WI-18AH	#45	PPM	28.9	26	140	87878	364	202	734
3/14/2014	12:37:50	WI-18AI	#46	PPM	28.87	23	136	76189	431	186	822
3/14/2014	12:38:26	WI-18AJ	#47	PPM	28.72	40	119	71219	240	219	679
3/14/2014	12:40:37	NIST2711a	#48	PPM	28.67	84	126	23798	1420	ND	368
3/14/2014	12:41:21	WIFS0310	#49	PPM	28.57	39	174	96466	1654	144	1318
3/14/2014	12:42:42	SiO2 Blank	#50	PPM	28.62	ND	ND	38	ND	ND	ND
3/14/2014	12:43:44	WI-19AA	#51	PPM	29.11	48	231	102251	686	219	1618
3/14/2014	12:44:25	WI-19AB	#52	PPM	29.04	37	176	81126	558	256	1299
3/14/2014	12:45:01	WI-19AC	#53	PPM	29.08	24	115	70994	177	145	394
3/14/2014	12:45:38	WI-19AD	#54	PPM	28.85	37	192	103586	584	270	1191
3/14/2014	12:46:14	WI-19AE	#55	PPM	29.07	30	168	85594	322	148	738
3/14/2014	12:47:32	WI-19AF	#56	PPM	28.86	27	170	92529	539	210	1285
3/14/2014	12:48:10	WI-19AG	#57	PPM	28.94	49	202	79978	598	138	1595
3/14/2014	12:48:46	WI-19AH	#58	PPM	29.04	35	157	99827	431	187	1075

Waipahu Incinerator XRF Readings (Grid Points 15-24)

Date	Time	Field Label 1	Reading	Unit	Elapsed Time Total	As	Cu	Fe	Pb	Ni	Zn
3/14/2014	12:49:22	WI-19AI	#59	PPM	28.97	42	189	99128	578	263	1419
3/14/2014	12:49:57	WI-19AJ	#60	PPM	28.87	38	163	100367	387	235	777
3/14/2014	12:52:29	WI-20AA	#61	PPM	28.99	22	202	130894	654	42	1076
3/14/2014	12:53:10	WI-20AB	#62	PPM	29.24	36	168	77435	523	154	1379
3/14/2014	12:53:48	WI-20AC	#63	PPM	29.12	41	95	57072	245	107	840
3/14/2014	12:54:27	WI-20AD	#64	PPM	28.91	35	149	77520	350	148	934
3/14/2014	12:55:07	WI-20AE	#65	PPM	29.08	44	184	84593	734	144	1785
3/14/2014	12:56:41	WI-20AF	#66	PPM	28.78	64	210	112442	681	243	1497
3/14/2014	12:59:15	WI-20AG	#67	PPM	28.86	53	195	123499	596	62	1547
3/14/2014	12:59:51	WI-20AH	#68	PPM	28.91	44	172	144671	723	94	1614
3/14/2014	13:00:26	WI-20AI	#69	PPM	28.82	38	199	88692	642	157	1625
3/14/2014	13:01:03	WI-20AJ	#70	PPM	28.94	54	203	115220	679	119	1538
3/14/2014	13:03:16	NIST2711a	#71	PPM	28.68	80	125	24352	1451	ND	374
3/14/2014	13:04:00	WIFS0310	#72	PPM	28.58	64	183	95647	1608	152	1295
3/14/2014	13:05:00	SiO2 Blank	#73	PPM	28.62	ND	ND	34	ND	ND	ND
3/14/2014	13:06:57	WI-21AA	#74	PPM	28.7	21	105	63935	168	157	490
3/14/2014	13:07:35	WI-21AB	#75	PPM	28.7	26	154	107689	133	256	414
3/14/2014	13:08:16	WI-21AC	#76	PPM	28.86	24	140	91630	209	190	595
3/14/2014	13:08:57	WI-21AD	#77	PPM	28.87	14	88	54604	167	129	492
3/14/2014	13:09:30	WI-21AE	#78	PPM	28.98	18	119	81204	238	160	630
3/14/2014	13:13:00	WI-21AF	#79	PPM	28.68	23	136	82300	321	192	482
3/14/2014	13:13:36	WI-21AG	#80	PPM	28.72	30	163	118390	125	340	397
3/14/2014	13:14:12	WI-21AH	#81	PPM	28.73	15	134	82312	213	195	614
3/14/2014	13:15:10	WI-21AI	#82	PPM	28.73	20	173	86216	245	208	677
3/14/2014	13:15:45	WI-21AJ	#83	PPM	28.74	22	139	96634	249	219	575
3/14/2014	13:18:51	WI-22AA	#84	PPM	29.22	13	79	39602	200	68	546
3/14/2014	13:19:34	WI-22AB	#85	PPM	29.05	17	90	53845	233	129	701
3/14/2014	13:20:21	WI-22AC	#86	PPM	28.72	29	155	95687	324	192	914
3/14/2014	13:22:21	WI-22AD	#87	PPM	28.96	8	77	38292	188	79	563

Waipahu Incinerator XRF Readings (Grid Points 15-24)

Date	Time	Field Label 1	Reading	Unit	Elapsed Time Total	As	Cu	Fe	Pb	Ni	Zn
3/14/2014	13:22:56	WI-22AE	#88	PPM	29.16	22	129	74365	352	209	873
3/14/2014	13:24:32	WI-22AF	#89	PPM	28.77	33	135	92693	239	221	592
3/14/2014	13:25:07	WI-22AG	#90	PPM	28.79	25	145	102857	259	187	604
3/14/2014	13:25:43	WI-22AH	#91	PPM	28.83	31	140	96828	298	201	689
3/14/2014	13:26:16	WI-22AI	#92	PPM	28.76	35	147	89409	283	235	658
3/14/2014	13:27:49	WI-22AJ	#93	PPM	28.67	88	132	24014	1396	ND	348
3/14/2014	13:29:02	NIST2711a	#94	PPM	28.71	67	176	99339	1532	138	1295
3/14/2014	13:29:54	WIFS0310	#95	PPM	28.61	ND	ND	28	ND	ND	ND
3/14/2014	13:33:17	SiO2 Blank	#96	PPM	28.85	29	156	116422	134	278	585
3/14/2014	13:34:13	WI-23AA	#97	PPM	28.97	28	145	94002	98	144	456
3/14/2014	13:34:50	WI-23AB	#98	PPM	28.85	23	148	80318	200	163	612
3/14/2014	13:35:28	WI-23AC	#99	PPM	28.97	34	152	91734	155	216	614
3/14/2014	13:36:05	WI-23AD	#100	PPM	28.89	43	173	121676	103	307	473
3/14/2014	13:36:40	WI-23AE	#101	PPM	28.94	27	130	78341	121	194	526
3/14/2014	13:38:20	WI-23AF	#102	PPM	28.88	47	199	127928	71	375	410
3/14/2014	13:38:55	WI-23AG	#103	PPM	28.8	50	196	142461	86	392	369
3/14/2014	13:39:30	WI-23AH	#104	PPM	28.8	47	211	155840	50	485	357
3/14/2014	13:40:10	WI-23AI	#105	PPM	28.85	53	176	168998	30	518	317
3/14/2014	13:40:44	WI-23AJ	#106	PPM	28.87	50	195	152493	29	520	286
3/14/2014	13:42:57	WI-24AA	#107	PPM	29.09	19	130	59937	280	83	972
3/14/2014	13:43:38	WI-24AB	#108	PPM	28.68	22	111	49121	241	79	794
3/14/2014	13:44:14	WI-24AC	#109	PPM	29.08	22	136	94666	194	73	621
3/14/2014	13:44:51	WI-24AD	#110	PPM	28.96	15	123	52919	274	50	890
3/14/2014	13:45:30	WI-24AE	#111	PPM	29.02	20	129	75404	298	105	909
3/14/2014	13:46:56	WI-24AF	#112	PPM	29.16	20	67	56081	117	107	423
3/14/2014	13:47:32	WI-24AG	#113	PPM	28.67	29	133	107721	131	110	527
3/14/2014	13:48:07	WI-24AH	#114	PPM	28.8	39	157	92797	249	123	862
3/14/2014	13:48:42	WI-24AI	#115	PPM	28.85	21	137	94979	188	62	636
3/14/2014	13:50:01	WI-24AJ	#116	PPM	28.86	19	142	107952	119	61	412

Waipahu Incinerator XRF Readings (Grid Points 15-24)

Date	Time	Field Label 1	Reading	Unit	Elapsed Time Total	As	Cu	Fe	Pb	Ni	Zn
3/14/2014	13:50:50	NIST2711a	#117	PPM	28.72	80	132	23789	1403	ND	355
3/14/2014	13:51:42	WIFS0310	#118	PPM	28.63	46	166	98374	1571	151	1269
3/14/2014	13:52:27	SiO2 Blank	#119	PPM	28.61	ND	ND	43	ND	ND	ND
3/14/2014	13:54:52	WI-24A1	#120	PPM	29.02	29	137	72839	327	77	990
3/14/2014	13:55:27	WI-24A2	#121	PPM	29	35	130	72817	319	69	997
3/14/2014	13:56:01	WI-24A3	#122	PPM	29	34	146	73806	329	57	994
3/14/2014	13:56:35	WI-24A4	#123	PPM	28.99	25	139	72520	323	71	961
3/14/2014	13:57:16	WI-24A5	#124	PPM	28.99	34	137	73952	325	73	1004
3/14/2014	13:57:53	WI-24A6	#125	PPM	28.99	31	145	72989	327	69	979
3/14/2014	13:58:30	WI-24A7	#126	PPM	28.99	30	147	72780	328	54	987
3/14/2014	13:59:04	WI-24A8	#127	PPM	28.99	29	140	73127	328	64	977
3/14/2014	13:59:41	WI-24A9	#128	PPM	28.99	35	139	73159	322	68	987
3/14/2014	14:00:16	WI-24A10	#129	PPM	28.99	26	140	73477	326	81	993
3/14/2014	14:00:57	NIST2711a	#130	PPM	28.69	102	116	24280	1404	ND	355
3/14/2014	14:02:05	WIFS0310	#131	PPM	28.58	64	192	97690	1668	153	1348
3/14/2014	14:02:55	SiO2 Blank	#132	PPM	28.62	ND	ND	34	ND	ND	ND

Appendix 3: Comparison of XRF vs Method 6010B (3050B) Data

Waialoa State Park Arsenic Study, Hilo (August 2013)

Comparison of XRF vs Method 6010B (3050B) for Discrete Sample A from each grid point.

Sample ID	Arsenic			Copper			Iron			Zinc		
	¹ XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference	¹ XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference	¹ XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference	¹ XRF Mean (mg/kg)	Method 6010B (mg/kg)	Percent Difference
WLP-1a	299	200	33%	69	27	61%	125,394	44,000	65%	211	130	39%
WLP-2a	175	140	20%	53	22	59%	104,687	49,000	53%	129	89	31%
WLP-3a	592	360	39%	87	32	63%	134,493	48,000	64%	249	140	44%
WLP-4a	801	410	49%	95	32	66%	166,650	44,000	74%	241	110	54%
WLP-5a	657	350	47%	98	32	67%	159,323	44,000	72%	267	110	59%
WLP-6a	379	300	21%	61	31	49%	109,194	44,000	60%	175	120	31%
WLP-7a	187	110	41%	70	34	52%	134,371	47,000	65%	246	160	35%
WLP-8a	257	180	30%	52	23	56%	123,985	44,000	65%	148	92	38%
WLP-9a	530	300	43%	81	34	58%	113,911	34,000	70%	177	93	48%
WLP-10a	490	330	33%	70	36	49%	124,602	45,000	64%	207	140	32%
WLP-11a	359	300	16%	60	31	48%	102,145	43,000	58%	162	120	26%
WLP-12a	499	350	30%	63	32	49%	117,880	43,000	64%	183	120	35%
WLP-13a	388	310	20%	75	36	52%	119,485	44,000	63%	240	150	38%
WLP-14a	496	380	23%	73	36	51%	126,061	46,000	64%	245	160	35%
WLP-15a	328	250	24%	79	34	57%	138,649	47,000	66%	241	130	46%
WLP-16a	498	300	40%	84	31	63%	153,723	45,000	71%	228	110	52%
WLP-17a	188	150	20%	64	31	51%	121,248	46,000	62%	208	140	33%
WLP-18a	223	180	19%	72	33	54%	118,340	43,000	64%	217	130	40%
WLP-19a	194	110	43%	87	44	50%	127,370	43,000	66%	299	190	36%
WLP-20a	203	130	36%	87	42	52%	116,951	40,000	66%	261	180	31%
WLP-21a	348	260	25%	83	46	45%	106,496	43,000	60%	253	190	25%
WLP-22a	277	150	46%	104	47	55%	137,115	42,000	69%	342	200	41%
WLP-23a	284	200	29%	67	31	54%	119,570	42,000	65%	226	140	38%
WLP-24a	196	160	18%	55	31	43%	104,287	44,000	58%	180	140	22%

Average: 31% Average: 54% Average: 64% Average: 38%

1. Average of ten XRF readings on original discrete sample that was subsequently sent to the lab for IS processing and Method 6010B analysis.